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A Survey and Assessment of the State of Low Impact Development in the Berkeley-Charleston-Dorchester County Region of Coastal South Carolina Emphasizing the Role of Landscape Architects in Stormwater Management

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A Survey and Assessment of the State of Low Impact Development in the Berkeley-Charleston-Dorchester County Region of Coastal South Carolina Emphasizing the Role of Landscape Architects in Stormwater Management

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ABSTRACT

Watersheds across the U.S., particularly population-dense coastal regions, are being impacted by cultural development preferences which promote an increase in impervious surfaces and ultimately increase the rate and volume of stormwater runoff. Low Impact Development (LID), a site specific form of green infrastructure (GI), is being adopted by many municipalities as an alternative stormwater management solution. Taking advantage of local ecological systems, LID addresses pressing growth requirements with the fundamental need to protect waterways, while also meeting federal regulations resulting from the National Permit Discharge Elimination System (NPDES). This thesis attempts to assess the state of LID in the Berkeley-Charleston-Dorchester (BCD) region of coastal South Carolina via background research and a survey of local land development professionals (landscape architects, planners and engineers). The intent is to ascertain patterns of LID awareness and usage, perceptions on benefits, barriers and opportunities, and ultimately provide strategies to facilitate widespread usage of LID in the BCD region.

DEDICATION

This thesis is dedicated to my husband, son, and family, for their unconditional support and love and to the town of Charleston, South Carolina for its inspiring natural beauty.

ACKNOWLEDGMENTS

I would like to take this opportunity to acknowledge those who have been instrumental in the completion of this thesis project. Thank you Professor Cari Goetcheus and Dr. Barry Nocks for your extended commitment, guidance, and support in helping me persevere and reach all of my goals. Also, a word of thanks to the local landscape architects, planners, and civil engineers whom enthusiastically participated in this project, providing the foundation for my work.

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CHAPTER ONE

INTRODUCTION AND RESEARCH QUESTION

For many years, stormwater management has been a field dominated by conventional engineering principles focused primarily on human safety with minimal concern for environmental consequences. As population growth and land-consumptive development preferences exacerbate hydrologic issues resulting from conventional stormwater management approaches, it has become apparent that these management approaches need to be reevaluated and a more sustainable approach advocated.

A relatively new approach to stormwater management, Low Impact Development (LID) requires strong advocates to espouse its usage and overcome a multitude of potential barriers. With a foundation based on principles supporting not only public health, safety, and welfare, but also the importance of protecting the land and its resources and their integral role in the land development process, theoretically, landscape architecture professionals provide a perfect medium for supporting and encouraging the use of LID. Only by attempting to understand their patterns related to awareness and usage of LID, as well as perceptions of benefits, barriers, and opportunities can accommodations be made that would allow for greater opportunities for LID usage among landscape architects.

Significance of Regional Water Quality and Quantity

"Water, water, everywhere, nor any drop to drink"
—*The Rime of the Ancient Mariner, Samuel Taylor Coleridge*

Water is a vital resource for every community across the globe. With about 70 percent of the earth's surface covered by water, there seems to be plenty to go around; yet, in the United States, issues with both water quantity and quality have become commonplace. Countless areas across the U.S. are subject to periods of drought and are forced to impose water usage restrictions. Conversely, there are other times when concentrated or lengthy precipitation events are creating serious flooding problems. Additionally, communities are restricting access to public bodies of water due to compromised water quality. Up and down the Eastern coast of the United States, it has become quite common for beach-goers to be prohibited from entering the water due to the presence of high levels of bacteria. In 2010, over 24,000 beaches were closed, the second-highest level since tracking of these types of events began 21 years ago (Dorfman and Rosselot, 2011). Shellfish beds are also subject to the same bacteria-driven closures. All of these water-related predicaments are influenced directly by the development decisions humankind has and continues to make, which in turn impacts the natural environment in which humans coexist.

Every region is shaped by water to some extent, based primarily on the geography of the region and relative proximity to water; certain communities are

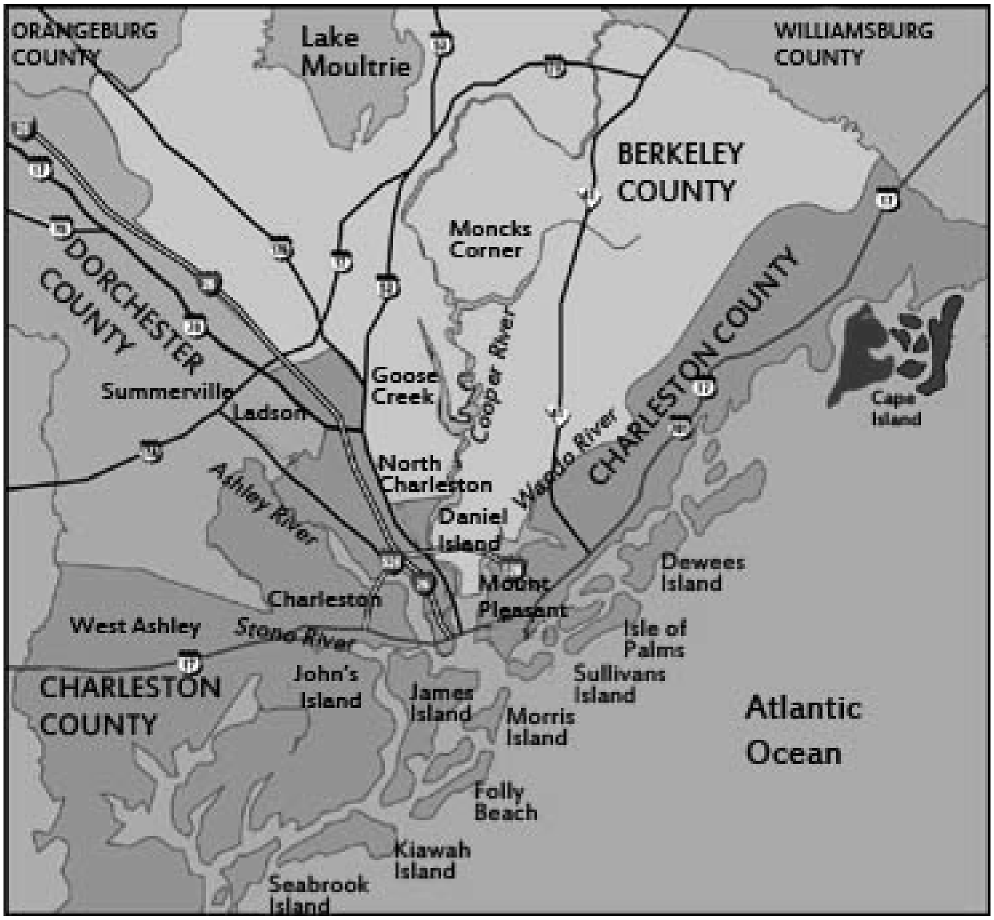

FIGURE 1.1: Water dominates the tri-county region of Berkeley-Charleston-Dorchester (adapted from SC Tri-County Properties)

more inherently affected by water—the Berkeley-Charleston-Dorchester (BCD) region of South Carolina is one of those places. The BCD region is defined by its water features and much of the local economy is intimately linked to its numerous beaches, rivers, wetlands, fresh water swamps and tidal marshes. In addition to its mild climate, historical qualities, and diverse culture, people and businesses are attracted to the region because of the abundance and variety of natural resource amenities that it offers for living, working, and playing. As the region becomes more urbanized to support the growing population, the impact of conventional development practices—which are prevalent in the region—will further burden the strained natural resources of the region, especially water resources. Ironically, the major reason for growth is also the feature most directly impacted—the coastal landscape and its unique ecology.

Growth and Development

Growth is not necessarily a bad thing; in fact, it is critical to a region's survival and prosperity. However, the manner in which the growth occurs is where the potential for harm exists. There are many influential professionals in both the private and public realms that collectively shape and define our built environment. Routine decisions made by individuals such as engineers, planners, developers, and landscape architects on where and how to build can have multi-faceted and enduring effects on the hydrological balance in a region. Today, one of the principal challenges of the built environment pertains to the creation and management of increased volumes and rates of storm water runoff, which results from precipitation which flows over land or impervious surfaces and does not penetrate into the ground.

Conventional vs. Alternative Stormwater Management

Conventional development practices incorporate copious amounts of impervious surfaces and conventional stormwater infrastructure such as curb, gutter, and pipe, and view the water as not only waste, but as a liability (State of

Washington, 2005.) An underlying principle of conventional stormwater management has been to quickly collect and convey water back into streams and other waterbodies through storm drains and other hard infrastructure (American Rivers, 2008). This mitigation-based approach often ignores environmental consequences associated with the increased rate and volumes of runoff.

Recently developed alternative stormwater management approaches—those that incorporate ‘green infrastructure’ (GI)—focus on techniques that complement existing natural systems by harnessing their beauty and functionality. Low Impact Development (LID) is a GI strategy for handling stormwater by managing runoff as close to its source as possible. This sustainable management approach aims to slow water and allow it to infiltrate in an effort to reduce the overall volume and rate of stormwater runoff. Benefits from this more natural approach are quite substantial and include filtering of pollutants, the moderation of floods, and the replenishing of groundwater (Ferguson, 1998).

Regional LID Usage

With the momentum of the environmentally friendly ‘green movement’ in full swing, some areas of the country, such as Portland, Oregon, have successfully adopted alternative stormwater management approaches, emphasizing the significance of the local hydrologic system. My preliminary research indicates that the BCD region has not yet fully embraced the idea of alternative stormwater management techniques, or LID. While there are a considerable number of LID-type extended detention ponds, within the region, there are a variety of other LID techniques that impart more substantial environmental benefits that have not been used. Due to the site specific nature of LID and other regional influences such as climate, geography and politics, the type and magnitude of obstacles (financial, political, physical, educational, scientific, and maintenance barriers) to the widespread implementation of LID, can vary greatly from one locality to another.

Scope of Research

LID first surfaced as an alternative approach to stormwater management in the 1990's, roughly around the same time that the Federal Government instituted its National Pollutant Discharge Elimination System (NPDES), which requires municipalities to focus on water quality by reducing the contamination in stormwater runoff discharged from Municipal Separate Storm Sewer Systems (MS4s). With the increased attention stormwater management has been receiving over the past three decades, why has the BCD region not completely adopted the idea of LID?

In order to fully comprehend the scope of this question, it is important to understand several factors that have the potential to significantly influence decisions regarding stormwater design and management. First and most basic is an appreciation for the hydrologic cycle, or the natural processes involved in the movement and storage of water on, above and below the earth's surface. Second is an intimate understanding of regional characteristics and policies. Features particular to Charleston such as its climate, topography, geology, and land cover will effect its own unique pattern of water movement and storage, while local stormwater policy will direct regional stormwater management approaches. Third is an inclusive comprehension of the principles behind LID, including its basic functionality and potential value. Finally, the influence of various local land-shaping professionals, such as landscape architects, civil engineers, and planners, is another critical component to understanding why and how certain stormwater management decisions are made. Assessing collective LID-related knowledge, resources, usage patterns, and perceived opportunities and constraints from these professionals will aid in comprehending how and why specific decisions, as well as overall strategy for stormwater management within the BCD region, are effected.

Hence, my overarching research question is:

As of 2011, what is the state of LID in the Berkeley-Charleston-Dorchester (BCD) region of coastal South Carolina?

Via a survey mechanism, this broad question will be answered by specifically asking landscape architects, planners and engineers:

1. What is your awareness and usage of LID?
2. What are your perceptions of the benefits, barriers and opportunities for LID?
3. What strategies might facilitate widespread usage of LID in the BCD region?

By identifying current patterns of alternative stormwater management awareness and use among various land development professionals (landscape architects, planners and civil engineers), as well as pinpointing potential benefits, obstacles and opportunities, directed approaches can be devised to assist the tri-county region with the creation and enhancement of an environment that is supportive of LID. Special attention will be paid to the role that landscape architects play in this process.

The subsequent pages of this document are devoted to discerning and elucidating both the pertinent information and processes involved in answering the research questions. Chapter Two, Methodology, describes what background information was gathered, how it was gathered, why this information is relevant, and the development and design processes involved with crafting and administering a survey, the primary data collection mechanism. Chapter Three, Hydrology and Urbanization, explains the basics of the hydrologic cycle and delicate nature of coastal ecosystems, while simultaneously illustrating the impact of current growth and development preferences and patterns on these hydrologic processes. Chapters Four and Five are devoted to understanding conventional and alternative approaches to stormwater management. These chapters detail the principles and functionality of each approach to stormwater management, as well as explanations of benefits and concerns related to the approaches. Chapter six identifies and discusses the range of barriers related to LID, while Chapter Seven reveals existing regional conditions in the Berkeley-Charleston-Dorchester (BCD) counties area of metropolitan Charleston, SC pertaining to physiographical traits, population and development trends, and regional stormwater regulations and management preferences. Chapter Eight provides a detailed description of the Alternative Stormwater Management Techniques and Barriers survey, while Chapter Nine reveals the detailed results of that survey. Finally, Chapter Ten, Conclusions, synthesizes the key components of this research offering directed approaches that may assist the BCD region in creating and enhancing an environment supportive of LID.

CHAPTER TWO

METHODOLOGY

The research questions being asked primarily of landscape architects, but also planners and engineers as land development professionals that influence stormwater management decisions, are:

As of 2011, what is the state of LID in the Berkeley-Charleston-Dorchester (BCD) region of coastal South Carolina?

1. What is your awareness and usage of LID?
2. What are your perceptions of the benefits, barriers and opportunities for LID?
3. What strategies might facilitate widespread usage of LID in the BCD region?

To answer the multi-part research question and facilitate my understanding for the processes influencing stormwater management in the BCD region today, a mixed model research approach was employed. To frame the research, a comprehensive literature review was undertaken on the following topics: the hydrologic cycle, urbanization patterns, impacts of urbanization on the hydrologic cycle, conventional and alternative stormwater management (including Low Impact Development), barriers to Low Impact Development, and pressing matters relevant to the location, hydrology and urban growth patterns of the BCD region. Following the literature review, qualitative and quantitative data was gathered via a survey instrument which included both closed- and open-ended questions. The survey data were summarized, categorized and analyzed via a detailed spreadsheet, which provided a regimented and logical structure affording comprehensive analysis and comparison of data within and among the survey questions. The combination of the literature review and survey results led to conclusions on how to influence future stormwater management decisions in the BCD.

Literature Review

Hydrology and Urbanization

In order to begin to comprehend the implications of increased impervious surfaces and increased stormwater runoff, it was important to identify the key components and interactions of the hydrological cycle. Current population and development trends and projections were analyzed, particularly along the coast, to assess exactly how this growth interferes with the hydrological cycle. When any change is imposed on a natural process, there are often numerous impacts, some more apparent than others. For this reason, it was important to understand the complexity and extent of environmental repercussions resulting from increased runoff in post-development hydrology.

Land use and management can significantly skew the distribution of water, considerably impacting precipitation and the movement of water in a watershed

(Brooks, 2003). Essentially, current development practices contribute to a loss of natural storage capacity, resulting in increased rates and volume of stormwater runoff (Kloss and Calarusse, 2006; Maryland Stormwater Design Manual, 2000; Rapid Watershed Planning Handbook, 1998). The ability to infiltrate water is essential to the filtering of pollutants, moderation of floods, and replenishing of groundwater (Ferguson, 1998). Studies have shown that water quality in receiving water bodies is degraded when the levels of imperviousness in a watershed reach ten percent and aquatic species can be impacted at levels less than ten percent ("Coastal Sprawl", 2002).

Present rates of land development are more than twice the rate of actual population growth ("Coastal Sprawl", 2002 and USDA Report, 2000). This is quite distressing, particularly for coastal regions which are home to more than 50 percent of the U.S. population, but only 17 percent of the total land. In 1997, 14 percent of the total coastal land area had been developed compare with four percent of developed land in interior counties ("Coastal Sprawl", 2002). If these trends continue, coastal regions can expect to experience not only an increase in the amount of impervious surfaces, but also higher overall percentages of imperviousness (Kloss and Calarusse, 2006).

Conventional and Alternative Stormwater Management Approaches

The next step in the literature review was to identify how the increased runoff was handled through conventional stormwater management approaches and to understand, how it is regulated, why it predominates today, and what the concerns our with this approach. Alternative stormwater management approaches, specifically Low Impact Development, were researched. LID philosophy, functionality, and benefits were discussed and compared with conventional stormwater management approaches and a comprehensive assessment of widespread barriers to LID was performed.

Impervious surfaces disrupt the flow of hydrological paths naturally present in a watershed creating the need to supplement or replace these natural flows with artificial drainage (“Stormwater Guidelines”, 2005); Without stormwater management systems, many urban areas would be subjected to frequent flooding from even minimal precipitation events (Valentine, 2007). Conventional stormwater management systems use a series of manmade infrastructure such as storm drains, pipes, and ditches to collect and transmit stormwater to receiving streams. Despite the fact that these municipal stormwater discharges are regulated by the EPA, there is often minimal to no treatment of the effluent (Kloss and Calarusse, 2006). In fact, the EPA estimates that combined sewer overflows (CSOs) are responsible for the release of about 850 billion gallons of untreated sewage and stormwater annually (EPA Report to Congress, 2004).

The existing network of centralized stormwater management infrastructure was developed by engineers in the early 20th century (Shuster et al, 2008); repairs and upgrades to maintain this aged infrastructure can be both time-consuming and expensive ("Green Infrastructure", 2010). In fact, the cost to maintain a stormwater system over a 20-25 year period is almost equal to the initial construction costs (Wiegand et al, 1986).

LID, an alternative green infrastructure (GI) approach, focuses on the root problem of imperviousness, as opposed to conventional strategies which address a symptom—stormwater runoff volume (Kloss and Calarusse, 2006). Emphasizing natural processes, LID techniques help filter common pollutants out of stormwater, assist in biologically or chemically degrading them (Kloss and Calarusse, 2006) and helps maintain lower surface water temperatures by infiltrating runoff into the ground ("Stormwater Strategies", 1999).

Multi-functional, it can be applied to almost any aspect of a landscape in an effort to control runoff including yards, buildings, roads, walkways, and open space (Weinstein, 2001); therefore, it can be instrumental in addressing localized stormwater issues or more widespread problems and can be adapted to newly developed land or as a retrofit solution (Kloss and Calarusse, 2006). Although GI is not expected to completely eliminate the need for conventional separate stormwater systems, it can significantly reduce the amount of water flowing into conventional systems, thus reducing the significant amount of “hard infrastructure” necessary to contain and treat stormwater (Valentine, 2007). Although it is a relatively new approach, existing research has validated LID as a simple, practical, and universally appropriate method for handling stormwater runoff (Coffman and Clar, 2001).

Unfortunately, there exist a multitude of barriers to the implementation of LID including: financial, political, physical, educational, scientific, and maintenance and operational issues. Despite these barriers, several large cities located across the U.S. including Seattle, Philadelphia, and Chicago, have embarked on green infrastructure projects and partnerships (Valentine, 2007), as well as a number of smaller towns.

LID in the BCD Region

Finally, an in-depth analysis of the BCD region of South Carolina was necessary to understand regional factors that might influence current preferences for local stormwater management approaches, such as population growth, climate, geography, and regional regulations. Part of the ‘lowcountry’, the BCD region has a lack of elevation which can be problematic for stormwater systems which often rely on gravity flow systems (Cappiella et al, 2010). Local soil conditions contribute to high rates of infiltration, which can create a potential for groundwater contamination (Cappiella et al, 2010) and the brief but intense thunderstorms common during the summer produce relatively short durations of concentrated runoff (BCD Plan, 2000). Collectively, these physiographical characteristics can present significant challenges to LID implementation.

Survey Development and Analysis

As a result of the literature review, it became apparent that speaking with BCD land development professionals would be important while formulating the survey content. Local professionals intimately linked to the development process, primarily landscape architects, but also engineers and planners in both the public and private sectors, were the focus, as on a daily basis these professionals engage in making and influencing decisions related to stormwater management solutions throughout the region. Their collective insight and perspective was recognized as valuable in comprehending where, how and why certain stormwater management choices are made.

Preliminary conversations

Several “feeler” phone conversations and meetings occurred with various professionals formerly or currently involved with stormwater in the Charleston area. Those individuals included a Charleston County Environmental Engineer, a representative from the South Carolina Department of Health and Environmental Control’s (SC DHEC) Office of Ocean and Coastal Resource Management (OCRM), a PhD graduate from the University of South Carolina’s Environmental

Health Sciences program, a Natural Resource Agent with Clemson's Cooperative Extension, and a local landscape architect.

Although the conversations varied, collectively, the goal of these conversations was to gain knowledge about the basic regulations and processes involved with stormwater management in the BCD region, gauge the overall acceptance and usage of LID in Charleston, and broadly understand any local or regional obstacles to implementing LID. All of this background information greatly informed the final development of a list of local professional types to survey as well as composition and content of the survey instrument. During the literature review, a variety of potential obstacles to LID were exposed. These preliminary discussions were beneficial in highlighting what obstacles might be relevant in the BCD area, as it would not be feasible to address every potential constraint in the survey. In addition, the conversations provided a practical glimpse of the types of LID techniques that were being used in project, which aided in identifying the right mix of more familiar and less familiar techniques around which to structure questions.

Target Audience Identification

The survey's target audience was based on a comprehensive list of private firms within the BCD region that employed landscape architects, including individuals practicing independently. Created through online searches, as well as information from the South Carolina Department of Labor, Licensing, and Regulation, and the American Society of Landscape Architects, the final list consisted of fourteen private practice firms. Through discussions with survey participants, additional survey prospects were identified in the public sector. These included landscape architects that were employed by local governments.

In addition, throughout the course of the survey process, it was repeatedly recommended by participants that the input of civil engineers be solicited as well. Therefore, a small number of engineers were included in the survey. The survey was also administered to some planners partially by the nature of their landscape architecture background or affiliation and others partially through happenstance. Although the survey was tailored to landscape architects in the private sector, the same survey was used for all participants, with slight re-wording of questions to tailor for the participants discipline or role.

Survey Content

To fully address the overarching and sub-research questions, seven sections were crafted for the survey: Background Information, Awareness, Use, Benefits, Barriers, Negotiating Barriers, and Opportunities. Background information (section one) was important to capture as variables such as the type of firm, size, and position will influence an individual's experiences and perceptions. Assessing awareness (section two) provides a possible indicator into overall LID usage factors including frequency of use and can identify potential gaps in knowledge. Qualifying and quantifying usage factors (section three) or understanding how often LID treatments are being used, how successfully the LID treatments are being implemented, and how usage is being influenced help highlight regionally relevant factors that may promote or inhibit use of LID.

Evaluating what benefits (section four) are perceived by various individuals involved in the development process can identify what is valued in a region or by different groups and can be useful for developing strategies aimed at encouraging and directing appropriate LID usage. Discussing barriers (section five) can highlight where potential efforts need to be focused to remove obstacles or to provide the proper support and direction to overcome them. Identifying barriers is just one step in the process to further the adoption of sustainable alternatives to stormwater management. Understanding what tools and resources local professionals need and rely upon to assist in overcoming barriers (section six), as well as the "paths of least resistance," are crucial components to equipping individuals with the resources to overcome potential roadblocks. Lastly, because of their profession, this group of individuals may be privy to certain information that could emphasize potential opportunities (section seven) valuable for removing barriers to and/or for promoting an increased usage of LID. Chapter Eight provides a detailed description of the survey.

Survey Implementation

Phone calls and emails were used to contact and schedule meetings with individual landscape architects, no matter if they were in a private firm or solo practice. At the meetings, the survey instrument guided the interview. During the face-to face interviews, participants were led through each survey question and detailed notes were taken to capture responses. Individuals were encouraged to supplement responses to questions in order to provide further explanation. Conversations were recorded and later reviewed with survey notes to ensure responses were accurately summarized.

Survey Results

Using a detailed spreadsheet affording comprehensive analysis and comparison of data within and across survey questions, the survey results were analyzed regarding the state of LID in Charleston, including an evaluation of overall LID awareness and usage, regionally relevant benefits, barriers, and potential opportunities. This analysis helped identify underlying factors potentially responsible for driving decisions related to LID usage in the BCD region.

Conclusions

Insight gleaned from all the previous work enabled conclusions to be drawn about LID in the BCD region. Further, guidance is proposed on removing barriers to LID so as to promote the usage of LID and GI-type stormwater management practices among local land development professionals in the BCD region

CHAPTER THREE

HYDROLOGY AND URBANIZATION

All organisms modify their environment to satisfy needs, some more than others—beavers build dams, ants create ant-hills, etc. Humans, by far, have had the most significant and widespread impact on the physical and biological systems of the earth, with the most apparent transformations occurring on land. . As the human population has continued to expand, so has our ‘footprint’; today, over eighty percent of the Earth’s surface has been transformed (National Geographic, 2011).

The origin of these terrestrial changes is linked to the beginning of agriculture, over 10,000 years ago. With a growing population and technological advances, particularly in transportation, the amount of land manipulated by humans continues to expand (National Geographic, 2011). Natural processes that once co-existed in a healthy environmental equilibrium are now being noticeably affected by rapid and unpredictable rates of change, by-products of our urbanizing civilization. This environmental equilibrium provided a level of tolerance to external changes, allowing the environment to adapt, while still maintaining a degree of stability over long periods of time (Mirovit͡skai͡a and Ascher, 2001).

As the earth's population expands and natural areas continue to be developed, a critical component of the earth's hydrological process is experiencing signs of distress. Most notably is the ability of the soil and vegetation to absorb rainwater and return it to the living ecosystem. This natural infiltration of rainwater confers significant benefits including the filtering of pollutants, the moderation of floods, and the replenishing of groundwater (Ferguson, 1998). Disruption of this natural process has serious environmental consequences including compromised water quality and availability, as well as flooding issues.

A serious threat to the hydrological balance is associated with the mounting rate at which stormwater runoff is being generated. Stormwater runoff results from precipitation that flows over land or impervious surfaces and does not penetrate into the ground. As humankind continues to develop land in order to accommodate a growing population, it is essential that stormwater management techniques are developed and implemented that facilitate the natural process of absorption and renewal.

Hydrologic cycle

The processes of absorption and renewal are basic components of the earth's hydrologic cycle. The cycle involves the continual movement of water, in each of its stages, within and between various storage points. Powered by the sun, this complex and dynamic cycle circulates water from the land and bodies of water to the atmosphere and back again (Brooks, 2003).

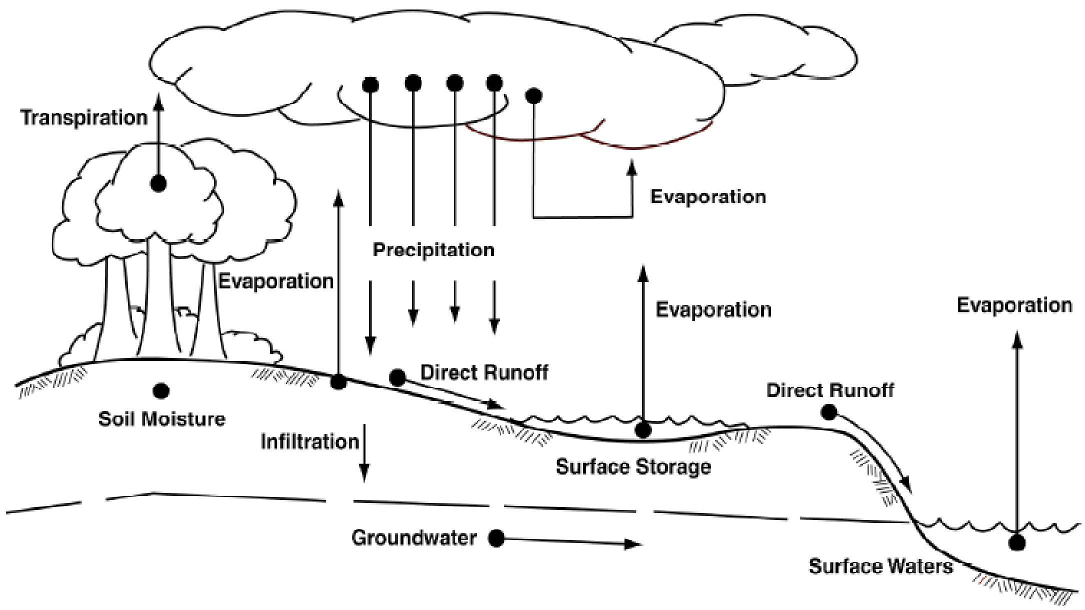

Figure 3.1: The Hydrologic Cycle (Horner et al, 1994)

Water transitions from the atmosphere, through bodies of water on the earth's surface and simultaneously passes through soil and rock layers underground and then returns once again to the atmosphere. This cycle, which has no definitive beginning or end, includes the movement of water through the following processes: evaporation, transpiration, condensation, precipitation, interception, infiltration, percolation, runoff, and storage (NOAA, 2011). Evaporation, transpiration, condensation, and precipitation are all processes that transport water between the earth's surface and the atmosphere. Water storage regularly occurs at various locations and instances within the atmosphere, on the surface of the earth and in the ground. Interception, infiltration, percolation, and runoff all involve the land-phase of the hydrologic cycle, or the interaction of water with the surfaces of the earth. Interception is the temporary detaining of precipitation on vegetation or in small land formations and depressions. Infiltration involves the movement of water from the ground surface into the soil. This movement is regulated by soil surface conditions and is also related to specific soil characteristics such as porosity, permeability, and antecedent moisture content. Once in the soil, gravity moves water downward through the various subterranean layers in a process called percolation (NOAA, 2011).

Water that has percolated into the zone of saturation, or the point where air no longer exists in the soil, has reached the water table and is called groundwater. At this point, water movement is based on the geologic boundary conditions. Some geologic formations support the storing of water in natural underground reservoirs and others promote a mostly horizontal movement. Aquifers are the result of specific underground formations that encourage the movement of water from one location to another (NOAA, 2011). Aquifers rely on precipitation in order to recharge or replenish depleted stores of water. Many processes, both natural and artificial, can influence the amount of rainwater that actually reaches an aquifer. Some of these processes include evaporation, human consumption, and runoff. As a result of this dependency on precipitation, aquifers are also subject to contamination. Water often accumulates pollutants as it moves across the earth's surface and the often increased rate at which water passes from the surface to the water table does not always allow for easy dilution or filtration of these pollutants (Idaho State, 2011).

Globally, groundwater supplied by aquifers accounts for roughly 97 percent of the world's total supply of drinkable water. In South Carolina, over 50 percent of residents rely on groundwater provided through either public utilities or individual residential wells. Additionally, many local industries require significant quantities of groundwater to support processes such as pulp, paper and textile manufacturing, food processing and metal finishing (SCDHEC, 2011). A 1985 South Carolina DNR report noted that several aquifers in the Charleston County area had already experienced substantial water-level declines and projections were that the decline would persist as the area's population and economy continued to expand (Park, 1985).

Runoff is the collective term used to describe the independent contributors of flow from a drainage basin or watershed that appears in surface streams. There are three runoff paths that water may take; this includes surface stormflow (overland flow), subsurface stormflow (throughflow), and baseflow (ground water). Together with precipitation that falls directly into a stream, these components form the total runoff in stream channels, also known as streamflow (NOAA, 2011). Streamflow is defined as the process by which water is conducted out of a watershed via a stream channel. During and shortly after a storm event, streamflow is dominated by stormflow. Baseflow, or ground water discharge to the stream channel, is the predominant contributor to streamflow between storm events and in the summer (Tate, 1996).

Post-rainstorm streamflow changes can be studied by the use of a hydrograph, which plots stream discharge against time. Hydrographs are valuable tools for their ability to illustrate the influences of land use changes on the discharge characteristics of a stream. Generally speaking, the shape of a hydrograph will be impacted if any one of the land-phases of the hydrologic cycle is varied while the others are held constant. For instance, if there is a decrease in the amount of vegetation in a watershed, there will be a corresponding increase in runoff as a result of the loss of the storage capacity. This will cause the unit hydrograph to rise higher (Lazaro, 1990), as depicted in Figure 3.2.

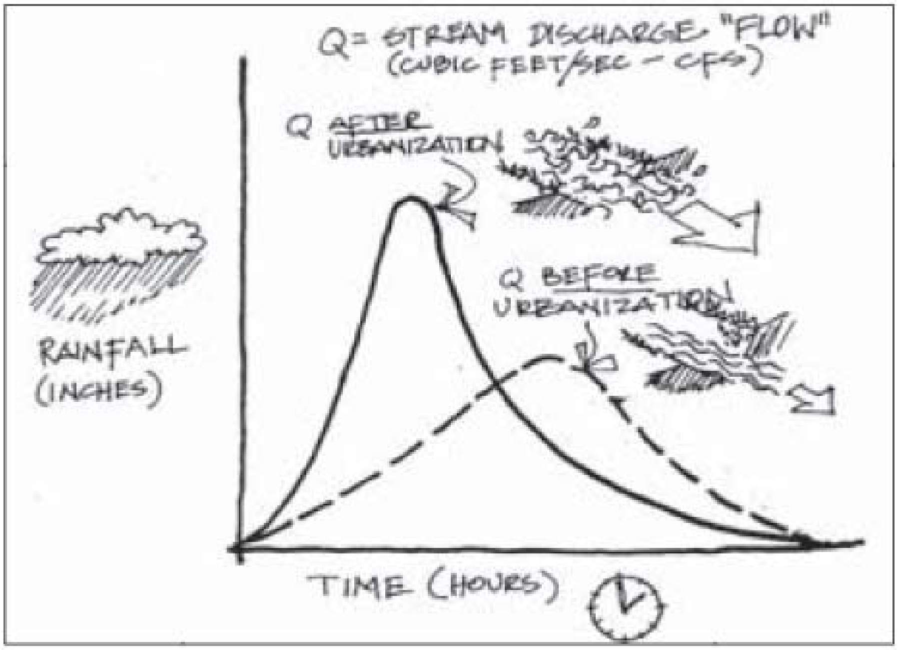

Figure 3.2: Typical pre- and post- development hydrographs for uncontrolled conditions ("Stormwater Guidelines", 2005)

Although the total volume of water present on the planet does not change, the distribution of water within the hydrologic cycle is in constant flux. This distribution of water can be significantly skewed by land use and management; human activities can have a considerable impact on precipitation and the flow of water into, through and out of a watershed (Brooks, 2003). It is becoming clear that development and urbanization trends are altering the dynamics of a watershed's delicate hydrologic balance. One of the most significant impacts is the inverse relationship that is created between overland flow and subsurface flow. Developed areas lead to an increase in the contribution of overland flow to receiving waters in minutes, while the storage and delivery capacity of subsurface flow over periods of hours, days, or weeks is seriously diminished (Booth et al, 2002).

Watersheds Defined

According to the U.S. Environmental Protection Agency (EPA), a watershed is a term that describes a region where all the water that falls on it, or is located under the soil, drains to the same place (EPA-What is a Watershed, 2011). It is common for a watershed to cover tens to hundreds of square miles and span several jurisdictions (Rapid Watershed Planning Handbook, 1998). Watersheds are divided into smaller geographic units, or subwatersheds, which typically have a drainage area of two to 15 square miles. This hierarchy of watershed management units is clearly illustrated in Figure 3.3.

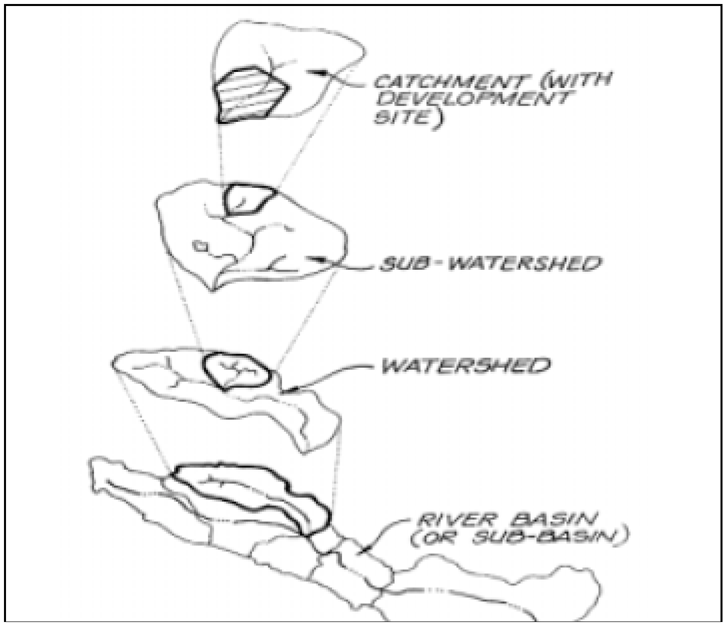

Figure 3.3: Watershed management units (Clements et al, 1996)

A basin is the largest unit within watershed management; it drains to a major receiving water body such as a larger river, estuary or lake. Drainage areas for basins are often quite large, covering several thousand square miles or more, and typically include sizeable portions of one or more states. Basins are further divided into sub-basins, which contain an array of diverse land uses. Sub-basins are composed of a group of watersheds, which, in turn, are broken down into subwatersheds. Within the subwatershed are located catchments, or the area that drains a specific development site to its first intersection with a stream (Rapid Watershed Planning Handbook, 1998).

Figure 3.4: A catchment depicting stream order (Shaver, 2000).

A network of small stream channels, or headwater streams, drains each subwatershed. Headwater streams, which can have perennial or ephemeral flow, are also referred to as ‘first order’ streams. As illustrated in figure 3.4, the junction of two first order streams creates a ‘second order’ stream and two ‘second order’ streams meet to create a ‘third order’ stream (Shaver, 2000). Although first order streams are the smallest classified streams, the sheer number and cumulative length account for 75 percent of the total stream and river mileage in the United States. The prevalence of headwater streams means that activities in the local landscape are directly translated to these streams, which ultimately impact major receiving waters. Therefore, streams are often good indicators of overall watershed quality (Rapid Watershed Planning Handbook, 1998).

Coastal Ecology

Along the coastal zone of the United States, a very valuable and vulnerable ecosystem with a distinct structure, diversity and flow of energy exists. This coastal ecology is composed of a wide range of natural habitats including wetlands, marshes, sand dunes, estuaries and barrier islands that provide a vast number of ecological, economical and recreational opportunities (Environmental Literacy, 2011). These habitats provide an important source of food, shelter and breeding territory for a variety of coastal and marine species and are especially significant for commercially important fish species. According to the National Oceanic and Atmospheric Association's (NOAA) Fishery Service, roughly 75 percent of commercially important fish have estuarine dependent life stages. Equally important are the environmental benefits that these ecosystems confer such as filtering of pollutants and nutrients and protection against the destructive energy and flood waters from coastal storms. Wetlands have been coined as 'the kidneys of the landscape', due to their location and function as downstream receivers of water and waste from both natural and human sources (Mitsch & Gosselink, 2007). Functionally, they slow water flow and allow time for sediment to settle and pollutants to be filtered ("Protecting Water Resources," 2006).

In addition to these important attributes, coastal habitats also create extensive and unique recreational opportunities, which translate into a valuable source of economic income. The U.S. Commission on Ocean Policy's Final 2004 Report found that U.S. coastal areas and coral reefs are responsible for attracting over 180 million visitors annually, which accounts for 85 percent of U.S. tourism revenue (Ocean Blueprint, 2004).

Urbanization and its Impact on the Hydrologic Cycle

Population and development trends

As land continues to be developed to support a growing and urbanizing population, the disruption to essential components of the hydrologic cycle, including flow and storage of water, will become more exacerbated. Recent studies indicate that the rate at which stormwater pollution occurs will likely increase. Of concern is the rate at which land is consumed for development; land consumption has surged to more than twice the rate of actual population growth. Between 1982 and 1997, the U.S. population grew 15 percent as compared to the staggering 34 percent growth in land consumption for development to accommodate that population in the continental U.S ("Coastal Sprawl", 2002 and USDA Report, 2000). This increase, which translates into an additional 25 million acres over a 15-year period, represents roughly 25 percent of the total amount of developed land in the contiguous United States (Kloss and Calarusse, 2006). For the most part, these gratuitous rates of land development are driven by cultural expectations and are not based on human necessity. These sizable population growth figures are only a component of a much larger issue, which is an insatiable cultural appetite for land consumption, combined with suburban development patterns and exponential growth in automobile usage (Beach, 2002).

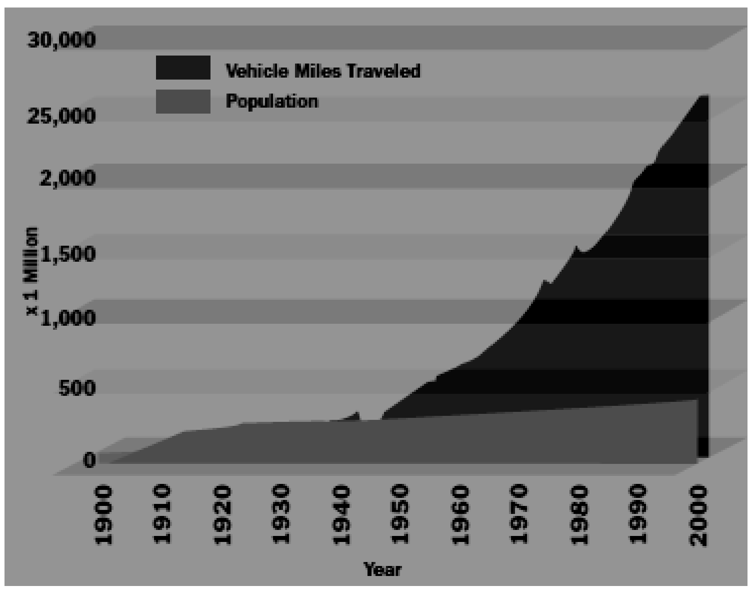

FIGURE 3.5: Over the past 20 years, the number of miles Americans drive annually has increased at a rate four times that of population growth, indicating that development has occurred further from jobs and that land consumption is dramatically increasing as well (“Coastal Sprawl”, 2002).

Trends of this magnitude are alarming for several reasons. First, is the rapid rate at which undeveloped land is being developed and second is the associated increase in stormwater runoff. Expectations, if population growth and land development continue at these same rates, are that a significant amount of land will be developed in the next few decades. Projections in population growth show an increase of 22 percent from 2000 to 2025, which using current development practices will demand an additional 68 million acres of land be developed (“Coastal Sprawl”, 2002).

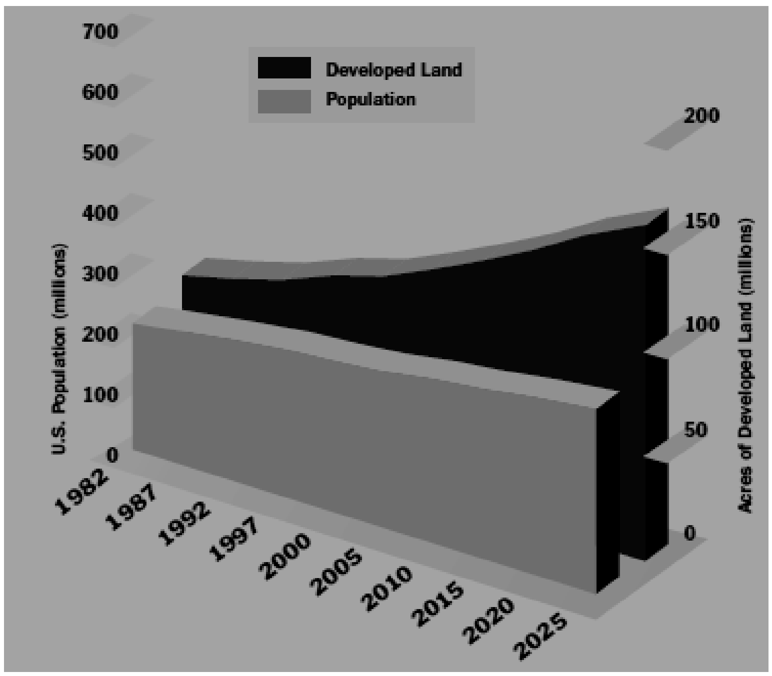

FIGURE 3.6: The rate of land development vs. the rate of population growth (“Coastal Sprawl”, 2002)

Coastal trends

These figures are even more distressing for coastal regions where urban stormwater runoff is already the largest source of ocean shoreline water pollution and a large portion of this projected population growth and new development will occur. Despite accounting for only 17 percent of the total acreage in the contiguous U.S., coastal counties are home to more than 50 percent of the U.S.

population. As a result of the combination of limited land and a highly concentrated population, coastal counties contain a greater percentage of development than interior counties. Statistics from 1997 show that 14 percent of the total land area had been developed compared with 4 percent of developed land in interior counties (“Coastal Sprawl”, 2002). If these trends continue, the indication is that the escalating population and development predicted in coastal regions will lead to not only an increase in the amount of impervious surfaces in coastal watershed, but also higher overall percentages of imperviousness (Kloss and Calarusse, 2006). Compounding the hydrological issues generated by current land development and urbanization trends in the generally more fragile ecosystem of coastal regions, is the corresponding surge in demand for water. In the last 30 years, the demand for water in the United States has tripled and globally, the demand doubles roughly every 20 years. This considerable imbalance in supply and demand has led investment bank Goldman Sachs to dub water as “the petroleum for the next century” (Cooper, 2008).

Hydrological Impacts

The movement, distribution and quality of water in a region is directly related to the land cover, geology, and biology within a watershed (Coffman, 2003). Although humankind’s ability to control geological and biological factors are rather limited, choices we make regarding land use and land cover have real consequences. Manipulations to land cover can effect significant hydrological changes in water quantity and quality. In natural or undeveloped areas, trees, vegetation and soils intercept, store, and slowly transmit a majority of rainfall through complex pathways (Hinman, 2005). Land cover in these natural settings allows most precipitation to infiltrate directly where it falls and very little, less than ten percent, is converted to runoff ("Protecting Water Quality", 2003 and Low-Impact Development Design Strategies, 2000).

When land becomes more 'urbanized', it affects a watershed's response to precipitation. Two of the most common changes include reduced infiltration and decreased water runoff travel time. The alterations result in a significant increase in both peak discharge and runoff volumes. Runoff volume is predominantly influenced by the amount of precipitation, as well as infiltration characteristics related to soil type, soil moisture, antecedent rainfall, land surface cover type, impervious surfaces, and surface retention (Stormwater Guidelines, 2005). Travel time, which is the time it takes for water to travel from one location to another within a watershed (Urban Hydrology, 1986), is based on slope, length of flow path, depth of flow, and roughness of the flow surface. Peak discharges are primarily determined by the relationship of these factors, along with the total drainage area of the watershed, the location of the development (including any encroachment into floodplains and loss of wetlands), impact of any flood control structures or storage facilities, and also the distribution of rainfall during a given event (Stormwater Guidelines, 2005).

Runoff is a natural part of the hydrologic cycle; however, the presence of impermeable surfaces, or manmade structures such as roadways, rooftops, and sidewalks, which are constructed with impervious materials like asphalt or concrete, dramatically increase both the amount and velocity of surface runoff, or stormwater runoff. Even natural land cover such as grass or dirt that has become compacted due to urbanization processes will shed water instead of absorbing it. Other alterations to land, including the commonly utilized practices of clearing and grading, will alter the hydrology of an area and compromise its ability to retain water on site (Maryland Stormwater Design Manual, 2000). Progressively, the by-products of humankind's development practices have and continue to lead to a loss of natural storage capacity and a resulting increase in stormwater runoff volume (Kloss and Calarusse, 2006; Maryland Stormwater Design Manual, 2000; Rapid Watershed Planning Handbook, 1998). The U.S. Environmental Protection Agency (EPA) estimates that a typical city block will generate five times the amount of surface runoff as a wooded area of similar size ("Protecting Water Quality", 2003). Figure 3.7 illustrates the disruption to the natural distribution of water that often occurs when land is developed and reinforces the dramatic alteration in the movement of water through the environment.

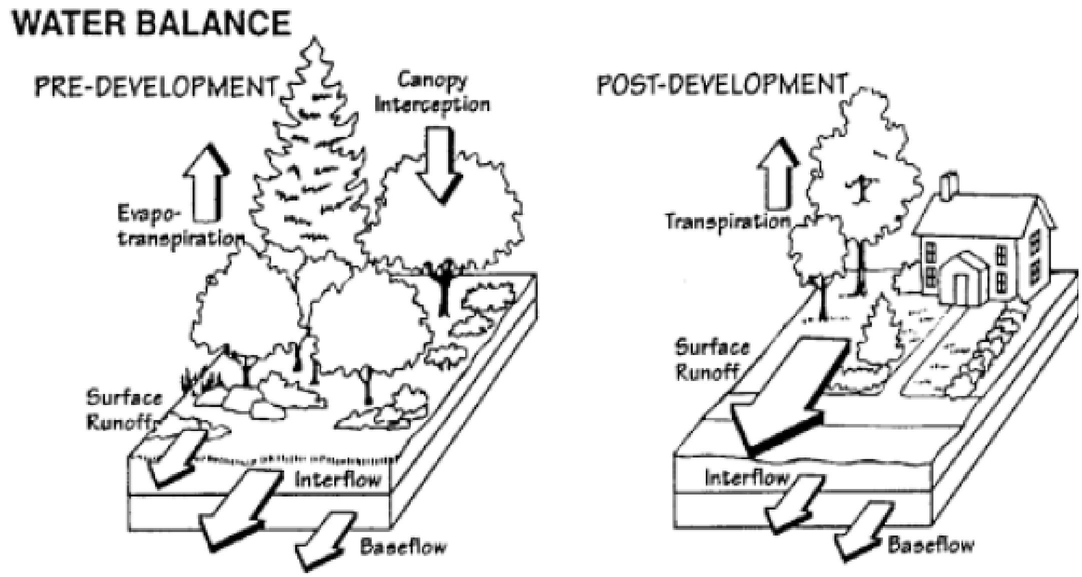

FIGURE 3.7: Differences in water balance on an undeveloped and developed site (Rapid Watershed Planning Handbook, 1998)

Ultimately, the excess water that does not get absorbed will flow across adjacent land eventually making its way into streams, rivers, and lakes. Surface runoff is problematic for several reasons relating to water quality and quantity. As water flows across impervious surfaces it accumulates various pollutants, sediment, chemicals and other debris—by-products of an urbanized society. If not treated, these contaminants are deposited directly into nearby waterways, adversely affecting water quality.

Some of the pollutants commonly found in urban stormwater runoff include: phosphorus and nitrogen-based nutrients, suspended solids, organic carbon, bacteria, hydrocarbons, trace metals, pesticides, and chlorides (Maryland Stormwater Design Manual, 2000). These pollutants come from a variety of sources as indicated in Table 3.1. A direct correlation between the level of imperviousness in a watershed and the health of its rivers, lakes, and

Pollutant	Source
Bacteria	Pet waste, wastewater collection systems
Metals	Automobiles, roof shingles
Nutrients	Lawns, gardens, atmospheric deposition
Oil and grease	Automobiles
Oxygen-depleting substances	Organic matter, trash
Pesticides	Lawns, gardens
Sediment	Construction sites, roadways
Toxic chemicals	Automobiles, industrial facilities
Trash and debris	Multiple sources

Table 3.1: Urban stormwater pollutants (adapted from Kloss and Calarusse, 2006)

estuaries has been established ("Coastal Sprawl", 2002); water quality in receiving water bodies is degraded when the levels of imperviousness in a watershed reach ten percent and aquatic species can be impacted at levels less

Water Body Type	Stormwater's Rank as Pollution Source	% of Impaired Waters Affected
Ocean shoreline	1st	55% (miles)
Estuaries	2nd	32% (sq. miles)
Great Lakes shoreline	2nd	4% (miles)
Lakes	3rd	18% (acres)
Rivers	4th	13% (miles)

Table 3.2: Urban stormwater's impact on water quality (adapted from Kloss and Calarusse, 2006)

than ten percent (“Coastal Sprawl”, 2002). When the level reaches 25 percent imperviousness, water quality and the overall health of the water body becomes seriously compromised. This relationship between impervious cover and stream quality at the watershed scale is represented in the Center for Watershed Protection’s Impervious Cover Model illustrated in Figure 3.8. Table 3.2 shows the percentage for which stormwater pollution has impacted certain monitored U.S. waters. In 2002, 21 percent of all swimming beach closings and advisories were attributed to the pollution from stormwater runoff (“EPA Report to Congress”, 2004). An estimate from Washington State claims that every 24 months, stormwater runoff from the streets of Seattle deposits a volume of oil equivalent to the Exxon Valdez spill into the Puget Sound (Logan, 2011).

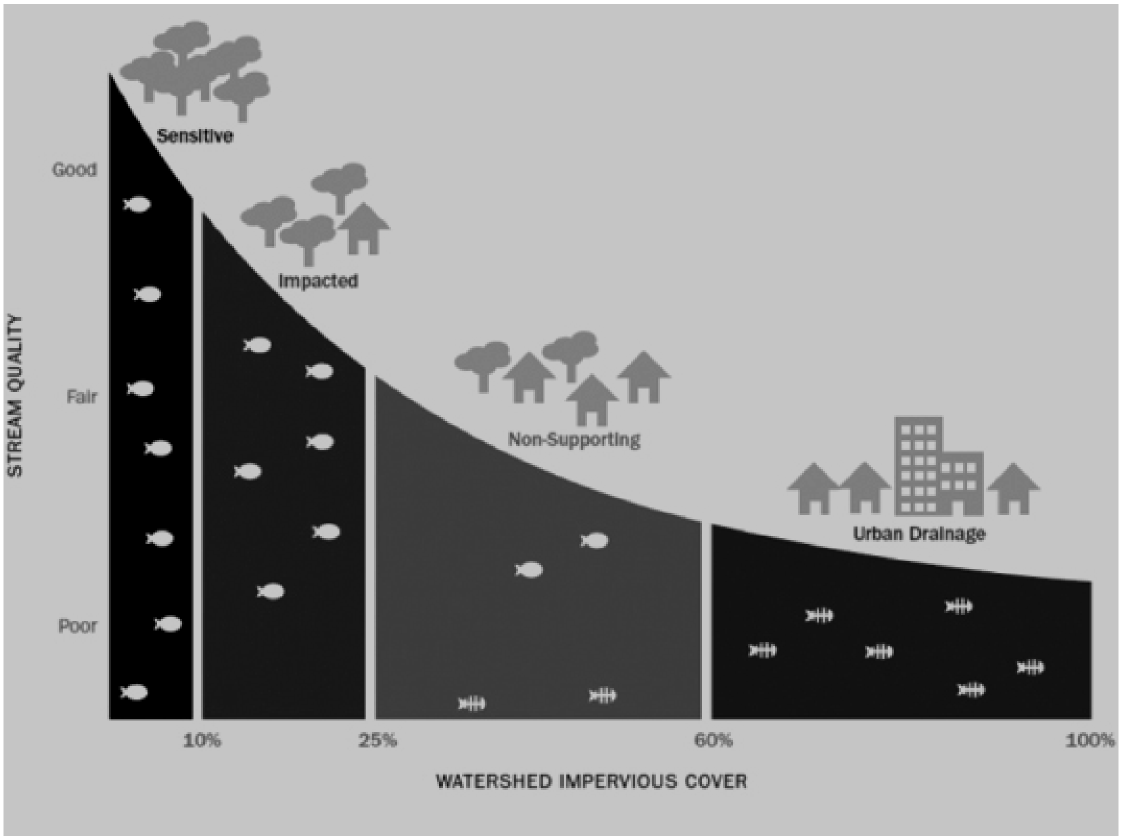

Figure 3.8: At ten percent imperviousness stream quality is impacted, at 25 percent stream quality and health are significantly compromised (Jacob, 2011)

Furthermore, stormwater runoff can have a thermal effect on receiving waters; runoff can be heated as it moves across hot impervious surfaces and will ultimately raise the temperature of nearby bodies of water. This temperature alteration can have a significant impact on aquatic life, as they are extremely sensitive to temperature change and are good indictors of riparian ecosystem health (Maryland Stormwater Design Manual, 2000). In addition to the decline in water quality, natural groundwater recharge capacity is impacted. Groundwater is not only an important source of drinking water, it is also essential to the health of many aquatic systems which rely on its steady discharge (Maryland Stormwater Design Manual, 2000).

Another issue is related to the significant amount of kinetic and potential energy that moving water possesses. Combined, these two forces have the ability to influence the geometry of streams and if directed, potential destruction of ecological and built environments. Post-development, there is a sharp increase in the frequency and magnitude of storm flows, which can be highly erosive to a streambank and also degrading to habitat (Maryland Stormwater Design Manual, 2000).

Figure 3.9: Erosion of the Sand River in Aiken, SC (Jason P. Julian, 2001)

As a result of conventional stormwater management's perspective of rainwater as problematic, the predominant focus is to channel away stormwater as quickly as possible. Consequently, large volumes of water are often displaced into surrounding streams in a matter of hours at a rate of up to one hundred times more water per minute than the stream is capable of accepting. This erosive effect can wreak havoc on aquatic habitat, directly impacting health and survival of aquatic species. For instance, in Vancouver, British Columbia there were once over 50 salmon- and trout-bearing streams; as of 2009, there were only two (Logan, 2011).

Further problems arise when flow events exceed the capacity of a stream and cause flooding issues in the adjacent land, or floodplain. Concerns over flood issues have intensified in recent years, particularly with the flooding disasters that occurred in the Midwest and Gulf Coast regions. Annually, the costs from flood-related damage total over $6 billion, not including Hurricanes Katrina, Rita and Wilma ("Floodplain Management", 2008). Although some overbank flooding is inevitable, and at times may be considered beneficial, generally speaking, these "overbank" floods pose hazards to property and can also be damaging to downstream drainage structures, culverts, and swales, all essential infrastructure related to collecting and collecting stormwater (Maryland Stormwater Design Manual, 2000).

Figure 3.10a: A traditional, unimpeded flood plain has room for the water to rise (www.geograph.com, accessed August, 2011)

Figure 3.10b: An urbanized floodplain in Pierce County, WA is subject to flooding (www.co.pierce.wa.us, accessed August, 2011)

Equally troublesome is the potential for the elevation of a stream's 100 year flood plain to become higher and the boundaries of its floodplain to expand, as a result of development and its escalating effects on stormflow. This concept, which is illustrated in Figure 3.11, creates a new threat of flooding to property and structures that previously were not at risk (Maryland Stormwater Design Manual, 2000).

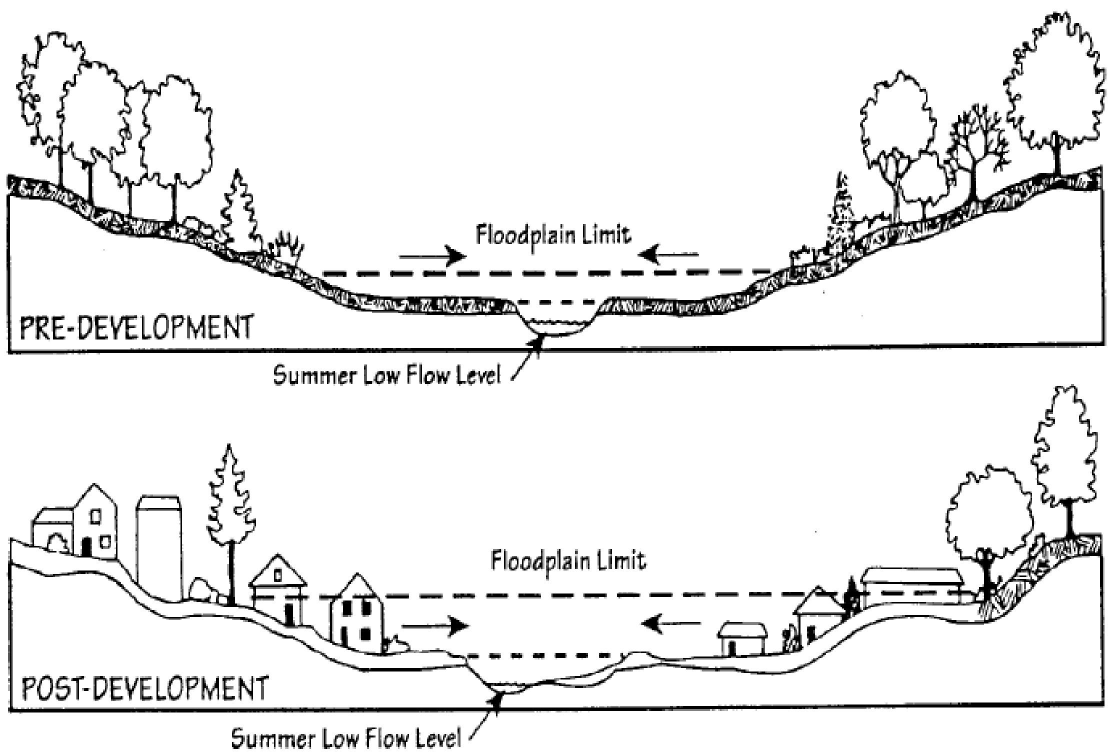

Figure 3.11: Change in Floodplain elevations (Rapid Watershed Planning Handbook, 1998)

Salinity Alterations

Along coastal areas, the unique interaction of fresh water and saltwater creates the potential for additional urbanization impacts in the form of salinity alterations and saltwater encroachment. Salinity is likely the most important factor impacting the distribution of organisms in estuaries, or partially enclosed bodies of water where saltwater and freshwater meet. It not only effects the distribution of organisms, but also plays a critical role in determining estuarine habitat, directly impacting distribution, abundance and composition of biological resources ("Salinity Alterations", 2011).

In nature, there exists natural cycles of salinity that fluctuate with tides, currents, wind and coastal shelf processes (Orlando et al, 1994). Humans influence salinity in a variety of ways including the alteration of hydrodynamic processes through the increased level of impervious surfaces. Another salinity related consequence of urbanized watersheds is related to a reduction in ground water resources. Ground water is extracted through pumping to meet a variety of human needs and relies on the hydrological cycle for natural recharge. As previously noted, impervious surfaces can directly impact groundwater recharge by both increasing runoff and decreasing infiltration capabilities. Any time the water table is lowered, the normal balance between the boundary of fresh and saltwater in aquifers, which relies on recharge rate and the flow of ground water into the ocean, is altered. When there is an absence of fresh water flow into the ocean, the aquifer is subjected to salt water intrusion ("Salinity Alterations," 2011). In order to maintain the balance in an aquifer, there is a rise of the boundary between fresh and salt water; for every three feet decline in water table, there is a concurrent 131 feet rise in saltwater (Dunne and Leopold, 1978). Saltwater encroachment can create a variety of problems for water supplies, including increased risk of intestinal illness (EPA, 1997), abandonment of supply wells (Wilson, 1982), and the need for desalinization plants (EPA, 1997).

Clearly, the impact of alterations to the hydrologic cycle from increased impervious surfaces has resulted in significant and far-reaching environmental consequences. This increase in impervious surfaces, which is a result a growing population with cultural preferences for sprawling patterns of land development. These preferences for land development are difficult to transform, yet changes need to be made in order to prevent irreparable damage to a valuable and essential natural resource.

CHAPTER FOUR

CONVENTIONAL STORMWATER MANAGEMENT APPROACHES

Some form of stormwater control measures have been in existence for many, many centuries. Urbanization, particularly impervious surfaces, disrupts the flow of hydrological paths naturally present in a watershed and subsequently, a need arises to supplement or replace these natural flows with artificial drainage ("Stormwater Guidelines", 2005). In the United States, both necessity and trial-and-error have driven the evolution of stormwater management from simple ditches to pipes and catch basins to detention basins and beyond. Today, the combination of impervious surfaces and developed land present the principal challenge to stormwater mitigation (Kloss and Calarusse, 2006). Efficiency in collecting and conveying stormwater has been and still is the primary focus of conventional stormwater management systems.

Without stormwater management systems, many urban areas would be subjected to frequent flooding from even minimal precipitation events (Valentine, 2007). Unfortunately, instead of treating stormwater as a resource, conventional stormwater management systems typically treat it as a liability (State of Washington, 2005) and a waste product, quickly funneling and concentrating the water back into streams and other water bodies via storm drains (American Rivers, 2008). Conventional approaches to stormwater management have evolved in a somewhat reactionary fashion, often ignoring environmental consequences.

Designed predominantly in response to urban flooding, the network of centralized stormwater management infrastructure that exists today was developed by engineers in the early 20th century (Shuster et al, 2008). This highly engineered and structure-based means for managing stormwater was implemented during the early growth of most U.S. cities with the sole objective of minimizing impact to the human built environment. Generally speaking, developed areas are designed using the “good drainage paradigm”, where the primary goal is to utilize impervious surfaces to efficiently collect and direct water away from human built structures as quickly as possible (Coffman, 2003). Today, this method prevails partially as a result of the exorbitant costs associated with any significant modifications to such a massive and intricate extant network.

Legal Basis for Stormwater Management

Generally, the legal foundation for stormwater management begins at the federal level with the Clean Water Act (CWA) through which the U.S. Environmental Protection Agency (EPA) sets standards for water quality programs and also ensures that state programs are being run within these guidelines. Under the CWA, the EPA regulates municipal stormwater discharges through a permitting structure known as the National Pollutant Discharge Elimination System

(NPDES). The NPDES permit program attempts to control water pollution through the regulation of point sources, or discrete conveyances such as pipes or man-made ditches, that discharge pollutants into U.S. waterways (EPA: NPDES, 2011). In South Carolina, the Department of Health and Environmental Control (SCDHEC) is charged with implementing the NPDES program.

At the municipal level, local codes, ordinances, regulations, and even incentives are used to control and manage various aspects of stormwater management such as water quality, drainage, and flood control. Ultimately, local governments are responsible for providing, supporting, and maintaining a functional stormwater infrastructure system; therefore any proposed land-disturbing activity, such as new or re-development, is subjected to these regulations and must provide stormwater management plans to be reviewed and approved by various state and local governmental bodies. Individual approaches to development and stormwater management will vary, yet each project will have an impact on the existing stormwater infrastructure system. Developer's decisions can add to or ameliorate some of the existing strain on stormwater infrastructure and can likely be influenced with the proper incentives.

Although the Clean Water Act has had a significant impact on the improved health of U.S. waters since it was established in 1972, today 40 percent of our nation's waters are still too polluted for fishing, swimming, and other recreational uses (“Getting in Step”, 2003). According to the Natural Resources Defense Council, the sheer volume of stormwater generated combined with space constraints in urban areas make the standard NPDES treatment and control requirements rather impractical. Typically, management measures include specific pollutant removal requirements and ‘performance based’ standards. Instead, the permit requirements for urban stormwater are that a stormwater management plan is developed and ‘best management practices’ are implemented without accountability to any specific requirements or standards (“Weathering the Storm”, 2004). As a result of these minimum control measures, compliance with NPDES permits does not necessarily result in the introduction of less polluted stormwater to our nation’s waterways (Kloss and Calarusse, 2006).

Conventional Types of Stormwater Management

Two different conventional systems are used in the public realm to control stormwater: 1) separate stormwater and sewer systems and 2) combined stormwater and sewer systems. Both systems perform the task of moving stormwater out of the watershed, albeit in different ways. A significant consequence of these conventional systems, which bypass local streams and ground water, is that the hydrological balance in a region can be seriously disrupted (“Green Infrastructure”, 2010).

Separate stormwater and sewer systems use a series of manmade infrastructure such as storm drains, pipes, and ditches to collect and transmit stormwater to receiving streams with minimal to no treatment (Kloss and Calarusse, 2006). Combined sewer overflows (CSOs), which are predominantly found in older cities, function by collecting and conveying stormwater in the same pipe system as domestic sewage and industrial waste (EPA: Combined Sewer Overflows, 2011). This combined effluent is sent through a wastewater treatment plant and cleaned to meet certain environmental standards prior to being released into natural and constructed waterways (Valentine, 2007). However, during periods of heavy precipitation, it is common for the volume of wastewater in the CSO to exceed its capacity, resulting in the release of untreated wastewater directly into nearby water bodies (EPA: Combined Sewer Overflows, 2011).

Concerns with Conventional Stormwater Management Practices

In addition to the significant environmental consequences associated with disrupting the hydrological cycle as previously discussed, there are several other problems posed by the use of conventional stormwater management practices. Overflow issues related to CSO systems are rather troubling. Estimates of CSO discharge indicate that approximately 15-20 percent is sewage and 80-85% is stormwater (Kloss and Calarusse, 2006). The EPA estimates that CSOs are responsible for the release of about 850 billion gallons of untreated sewage and stormwater annually (EPA Report to Congress, 2004). Not only is this problematic for the health of our waterways, but also the health of human beings. A hospital study performed in the Milwaukee, Wisconsin area demonstrated a spike in the number of children with serious diarrhea after the city's sewers overflowed (Logan, 2011). During the late 20th century, efforts were made by cities to reduce CSO sewer overflows. Many of these cities separated combined sewers, expanded treatment capacity or storage within the system, or replaced faulty pipes; all of these efforts are enormously time-consuming and expensive ("Green Infrastructure", 2010).

A recent study reinforces the hefty price tag associated with constructing and maintaining separate stormwater systems. The study estimates that the amount of money spent on treating both the quantity and quality of stormwater ranges from $2,000 to $50,000 per impervious acre. Only one out of every three dollars spent on stormwater management construction is dedicated to quality control purposes, the majority is used for flood control purposes (Rapid Watershed Planning Handbook, 1998). Maintaining stormwater systems is a necessity and the burden of covering the associated costs falls on local government or landowners. The cost to maintain a stormwater system over a 20-25 year period is almost equal to the initial construction costs (Wiegand et al, 1986). In the EPA's 2004 *Clean Watersheds Needs Survey*, it was estimated that nationwide capital investments for managing stormwater and wastewater pollution over a 20-year period would be roughly $202.5 billion. This figure includes $54.8 billion for

CSO corrections and $9 billion for stormwater management. In response to the numerous costs associated with building, maintaining, and retrofitting stormwater management systems, most local governments have instituted stormwater utilities. Every property owner is charged a small fee for their use of the storm drain network and the cost is usually based on the total amount of impervious area on the property (Rapid Watershed Planning Handbook, 1998). Nationally, the average for a residential stormwater utility fee is approximately $40 per year (EPA: Funding Stormwater Programs, 2008).

With such significant financial and environmental tolls, questions regarding efficacy and cost-effectiveness of conventional stormwater methods in meeting the objectives of today's complex environmental issues and water resource objectives are being raised by many jurisdictions ("A New Paradigm", 2000). Clearly, existing infrastructure is incapable of managing stormwater in a manner that adequately protects and improves water quality. Deficiencies exist in the ability to both reduce the volume of stormwater runoff from urban environments and effectively remove pollutants. Essentially, these problems are by-products of the real issue; the inability of the current stormwater management approaches to effectively address the fundamental issue of imperviousness (Kloss and Calarusse, 2006). From urban to suburban to rural, all sectors are faced with similar stormwater issues; however, the population growth, quantity of land consumption and impervious surfaces found in more developed urban and suburban areas, makes the need for innovative, sustainable solutions to stormwater management more pressing in those areas.

CHAPTER FIVE

ALTERNATIVE STORMWATER MANAGEMENT APPROACHES

Recently, many communities in the U.S. and abroad have begun to recognize the value of stormwater and the magnitude of proper management (American Rivers, 2008). Despite best intentions, limitations in conventional stormwater technology are preventing the fulfillment of modern watershed protection objectives related to groundwater resources, recreational activities, and ecological habitat. These limitations are a direct result of the conventional stormwater management approach which puts an emphasis on addressing the symptoms, or large volumes of rainwater, instead of focusing on the problem, which is our current development practices that ensure continued high levels of imperviousness (Kloss and Calarusse, 2006).

Fortunately, alternative stormwater management solutions exist that can provide similar functional capacities of flood control and drainage but without the negative environmental impacts. In fact, these alternatives—which focus on the root cause of our stormwater crisis—actually promote and protect existing natural processes and resources. Collectively, these alternatives are designated as 'green infrastructure.'

Green Infrastructure

Green infrastructure (GI) is viewed as a comprehensive approach to water quality protection that is characterized by the use of both natural and constructed systems. Collectively, these systems, which can be implemented at a regional, community, or site level, are designed with natural hydrologic processes in mind and work in conjunction to effectively slow and allow infiltration of stormwater where possible, allowing the environment to manage water naturally ("Green Infrastructure", 2010). Green infrastructure is not expected to completely eliminate the need for conventional separate stormwater systems, but by reducing the amount of water flowing into conventional systems, GI can reduce the significant amount of "hard infrastructure" necessary to contain and treat stormwater (Valentine, 2007).

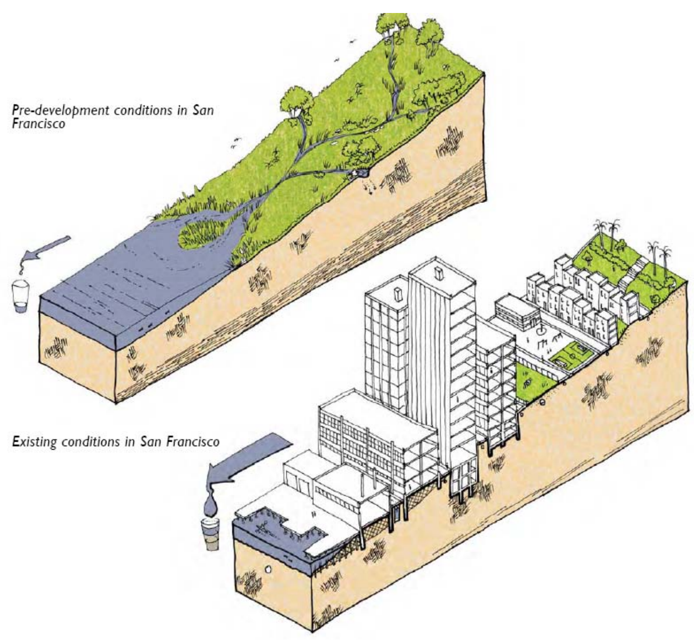

Figure 5.1a: Pre- and post- development runoff conditions in San Francisco (San Francisco Public Utilities Commission, accessed August 2011)

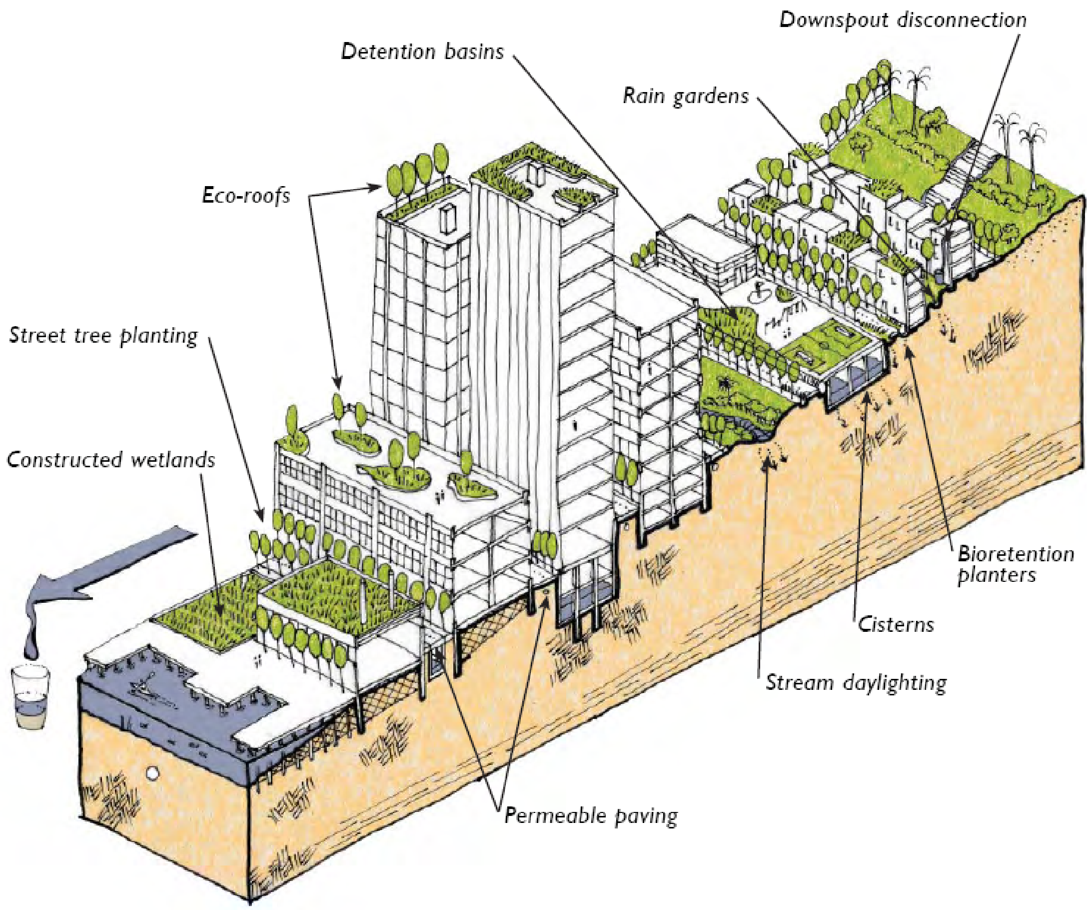

Figure 5.1b: Post-development runoff conditions with green infrastructure (source: San Francisco Public Utilities Commission)

At the regional or watershed scale, green infrastructure emphasizes the protection and preservation of existing natural resources. Unified networks of preserved or restored land and water provide essential environmental functions. Examples of this large-scale green infrastructure include water resource, corridor and habitat protection. At the community and neighborhood scale the focus is on guiding and shaping local development policy that respects natural resources and the natural hydrologic flow. There is an emphasis on planning and design strategies that can achieve healthy environments, which provide modern amenities and conveniences with a reduced ecological impact. These approaches incorporate ideas such as compact development and urban forestry principals. Examples include the use of cluster development, reduction in road width and number of parking spaces requirements. At the site scale, green infrastructure is also referred to as Low Impact Development, or LID ("Green Infrastructure", 2010). Low Impact Development stormwater management strategies are based on the principle that managing runoff as close to its source as possible will contribute to an overall reduction in runoff volumes and pollutant loads (EPA: Low Impact Development, 2011). LID focuses on the root problem of imperviousness, as opposed to conventional strategies which address a symptom—stormwater runoff volume (Kloss and Calarusse, 2006).

Low Impact Development (LID)

The concept of LID was first introduced in the 1990's by Maryland's Prince George's County's Department of Environmental Resources and was developed specifically to address runoff issues associated with new residential, commercial, and industrial suburban development ("Design Strategies", 1999).

Today the concept has many similar names including: green engineering, sustainable stormwater management, natural drainage, stormwater best management practices (BMPs), water-sensitive urban design, context sensitive design, and flow control BMPs (Miccio, 2010). Essentially, each of these strategies employ in situ alternatives, both natural and manufactured, as compared to the conventional structural approaches of containment and treatment presently used to handle stormwater (Valentine, 2007).

LID philosophy

LID is a land management philosophy which focuses on mimicking the pre-development hydrologic functions of an area, including volume, frequency, recharge, and discharge (“A New Paradigm”, 2000), in order to prevent measurable harm to natural aquatic systems (Hinman, 2005). The integration of site planning and stormwater management during the initial design phase of a site is used to achieve two things: a hydrologically functional landscape which emphasizes conservation; as well as the use of on-site natural features and small-scale engineered hydrologic controls (Hinman, 2005). Functionally, LID accomplishes the simulation of pre-development hydrologic functions by minimizing, detaining, and retaining post-development volumes of runoff uniformly across the site (“A New Paradigm”, 2000). This approach, which promotes natural processes such as infiltration and evapo-transpiration, attenuates urban runoff flow and pollution by linking various LID practices into a cohesive system (EPA-Reducing Stormwater Costs, 2011) as well as the collection and reuse of stormwater (“Green Infrastructure”, 2010).

Category/Characteristic	Conventional Engineering	Ecological Engineering
Project goal	Single purpose	Multiple benefits
Benefits to the ecosystem	Low priority	High priority
Structures	Concrete, steel, human-made, "hard"	Landscape/aquatic features, natural, "soft"
Energy source	Fossil fuel combustion, electricity	Solar, gravity, plants, animals
Material movement mechanisms	Pumps, blowers, conveyors	Convection/gravity, plant/microbial processes
Processes	Human-driven, human regulated	Natural, self-regulated
Climate and landscape setting	Relatively unimportant	Critical
Useful lifespan	Relatively short	Relatively long
Performance	Controlled	More variable
Robustness	Often low	Usually high
Operation and management costs	High	Low
Land Requirements	Low priority	High

Table 5.1: Comparison of conventional engineering approaches to stormwater management and more sustainable, green infrastructure approaches such as LID or ecological engineering (adapted from Barrett, 1999).

These basic management practices of LID, lends the approach to being a practical and beneficial application for not only new development but also for existing urbanized watersheds that often have space and existing infrastructure constraints with which to contend (Coffman and Clar, 2001). The decentralized and micro-scale approach means that many LID techniques consume only a small amount of land on any give site and they can be easily integrated into existing infrastructure such as roads, parking areas, buildings or open space. Much of this single-purpose infrastructure, including parking lot islands, street medians, tree planter boxes and landscaped areas near buildings can be effectively converted into multi-functional, specialized stormwater treatment systems using LID technologies (EPA-LID Literature Review, 2000). Furthermore, the naturalized form of LID can often be a welcome addition, providing beauty and desirable public open space to an urbanized area ("Design Strategies", 1999; Shaver, 2000).

Although hydrological function and water quality within a watershed become impaired with merely a ten percent impervious land cover ratio, that percentage ("Coastal Sprawl", 2002), does not imply that low-density development is preferred over denser types of development. While it may be true that low-density development generally allows a majority of a lot to remain unpaved or unbuilt, this assumption does not take into account the significant amount of off-site impervious coverage in the form of roads and parking lots, which are required to support this type of land consuming development. Additionally, many disturbed surfaces, such as lawns, that might appear pervious are often compacted, significantly compromising the ability of the land to infiltrate runoff ("Protecting Water Resources" 2006). In reality, low density development does not necessarily reduce negative impacts to watershed quality, it just spreads them out ("Protecting Water Resources" 2006). In fact, recent research from the EPA, the Center for Watershed Protection, and other environmental agencies supports higher density infill projects, as studies demonstrate that there are more water quality benefits than with low-density development. Moreover, the Center for Watershed Protection reported that, "Increasingly, urban redevelopment and infill projects are emerging as a means to help rejuvenate sagging city centers, while simultaneously providing opportunities for more environmentally friendly growth ("Stormwater Guidelines", 2005)".

The notion that cities are inherently "bad" for water quality is being contradicted by real examples of properly designed, dense, green development that are benefiting not only the community and local economy, but also the natural environment, including water resources ("Stormwater Guidelines", 2005). A great example of a coastal city that has benefited from green dense redevelopment is the town of Emeryville, California, situated between Oakland and Berkeley on the San Francisco Bay. Formerly an industrial hub, city managers attempted to revive the declining industrial city through the promotion of an innovative set of green infrastructure policies.

In the 1990's the city's initial attempt at spurring growth and re-development was to "cap" the contaminated land, or brownfields, with parking lots and pavements. This purely functional approach created a large impervious landscape that was not only detrimental to water quality, but also to pedestrian access and quality of life. Through a 2004 EPA Smart Growth grant, the city of Emeryville devised a customized and comprehensive set of stormwater policies and guidelines to help promote more sustainable solutions to the brownfield dilemma. Both city staff and the general public collaborated in workshops to develop a set of goals which included: improving water quality, protecting habitat value, using land efficiently, embracing natural processes, providing cost-effective solutions, and fostering unique and attractive streetscapes and development.

These guidelines, which were geared toward designers and developers, were intended to help provide a vision for integrating ‘green’ stormwater management and also innovative parking solutions into the site planning and building design of retrofit development. Accounted for within the guidelines are specific constraints faced by the city, including heavily urbanized sites, compacted and contaminated soils, and a high ground water table. Examples of general design solutions for stormwater treatment such as tree preservation and planting, green roofs, bio-filtration and permeable pavement are provided, along with specific guidance in the siting and sizing of specific treatments (“Stormwater Guidelines”, 2005; “Green Infrastructure”, 2010). This holistic approach by the city of Emeryville can best be summed up by a line from the ‘Goals’ section of the guidelines, which states:

> “One must understand that the environment, urban or otherwise, is not a collection of discrete units, rather everything overlaps and everything is connected. In order to have any meaningful impact on complicated problems, solutions must understand this premise (“Stormwater Guidelines”, 2005).”

Benefits of LID

Low Impact Development's decentralized and flexible approach to stormwater management not only addresses the issues of runoff and imperviousness, it can also contribute to a potential number of community benefits ranging from enhanced environmental, social, economic and public health factors. There are a myriad of benefits that can result from a more naturalized method of handling stormwater, some are easier to quantify than others. Table 5.2 illustrates the broad scope and scale of benefits that can be provided through the use of green infrastructure approaches.

Flexible

In contrast to conventional stormwater management techniques, LID provides a flexible and decentralized solution for managing and treating stormwater at its source. A wide range of strategies can be implemented in order to achieve specific stormwater goals relating to runoff speed, volume, and quality and the approach can be tailored to the needs or circumstance related to a particular site or community. LID can be applied to almost any aspect of a landscape in an effort to control runoff including yards, buildings, roads, walkways, and open space (Weinstein, 2001). As a result of this flexibility, LID techniques can be implemented in a variety of scales including the site level, neighborhoods, cities, or regionally. It can be instrumental in addressing localized stormwater issues or

Environmental	Increase carbon sequestration
	Improve air quality
	Additional recreational space
	Efficient land use
	Improve human health
	Flood protection
	Drinking water source protection
	Replenish groundwater
	Improve watershed health
	Protect or restore wildlife habitat
	Reduce sewer overflow events
	Restore impaired waters
	Meet Regulatory requirements for receiving waters
Economic	Reduce hard infrastructure construction costs
	Maintain aging infrastructure
	Increase land values
	Encourage economic development
	Reduce energy consumption and costs
	Increase life cycle cost savings
Social	Establish urban greenways
	Provide pedestrian and bicycle access
	Create attractive streetscapes and rooftops that enhance livability and urban green space
	Educate the public about their role in stormwater management
	Urban heat island mitigation

Table 5.2: Benefits of green infrastructure (adapted from “Green Infrastructure”, 2010)

more widespread problems and can be adapted to newly developed land or as a retrofit solution (Kloss and Calarusse, 2006). Conceivably, almost any site could apply some form of LID practice.

Effective and sustainable

By replicating predevelopment hydrology, green infrastructure can effectively reduce both the volume of stormwater and also the amount of pollutants that enter into our waterways. Research has validated LID as a simple, practical, and universally appropriate method for handling stormwater runoff (Coffman and Clar, 2001). The natural processes employed by LID techniques help filter common pollutants out of the stormwater and assist in biologically or chemically degrading them (Kloss and Calarusse, 2006). In addition, the common practice of infiltrating runoff into the groundwater helps maintain lower surface water temperatures (“Stormwater Strategies”, 1999). Furthermore, significant benefits result from the reduction in stormwater entering current infrastructure; less volume entering results in a decrease in the volume of stormwater discharged by separate stormwater sewer systems and also lessens the risk of overflow in combined sewer systems (Kloss and Calarusse, 2006).

Multi-functional

Another positive characteristic of LID is that most applications are multi-functional. This is clearly illustrated by examining the value added by the installation of a green roof. Not only does the green roof reduce stormwater runoff, it also conserves energy, extends the life of the roof, helps to reduce the urban “heat island” effect, improves air quality, provides wildlife habitat and contributes to urban aesthetics (Valentine, 2007). Along with the multitude of environmental benefits and the aesthetic appeal, additional value is gained from the associated increase in vegetation. This greenery provides enhanced “quality of life” factors by contributing to livability, value, and sense of place. These factors can have a direct influence on property values, re-development potential, and marketability (“Stormwater Strategies”, 1999; “Design Strategies”, 1999; Shaver, 2000).

Economical

Furthermore, because of the emphasis on natural processes and micro-scale management practices, LID can often be less expensive than centralized stormwater strategies. Not only are there cost savings associated with implementation and maintenance of LID, but they generally tend to have a longer life cycle cost than conventional stormwater management solutions (EPA-LID Literature Review, 2000). LID used in place of, or in conjunction with, conventional stormwater systems, allows for a reduction in costs associated with the construction, operation, and maintenance of conventional stormwater infrastructure. The cost reduction, which can be as much as 25 to 30 percent compared to strictly conventional approaches, can be attributed to a reduction or elimination of infrastructure such as pipes, inlet structures, curb and gutter, and also from minimized use of grading and clearing practices ("A New Paradigm", 2000; Green Infrastructure, 2010). Also, the flexibility of LID creates opportunities for alternate funding sources. Compared to conventional strategies which generally rely on tax money to fund public work projects, green infrastructure costs can be absorbed by the government, developers, or even local property owners.

Less quantifiable but equally important are the 'ecosystem services' provided by the natural environment. This term refers to the often underappreciated goods and services that are conferred by healthy ecosystems. Examples of these 'services' include the pollination of crops by birds and insects, the filtration of air and water by vegetation and soil, and the flood protection that wetlands offer. Difficult to quantify, the collective value of 'ecosystem services' is often overlooked when land use decisions are being made ("Case for Sustainable Landscapes", 2009). In Houston Texas, calculations by the non-profit conservation organization, American Forests, demonstrate just how cost effective simple, green infrastructure alternatives can be. It was estimated in 2000, that Houston's tree canopy cover reduced the volume of stormwater runoff by 2.4 billion cubic feet (Valentine, 2007). Based on a $0.66 per-cubic-foot cost of stormwater management in that area, it is estimated that the urban forest contributed a total savings of $1.33 billion in one-time construction costs

(Valentine, 2007). Additional savings are recognized by a decreased volume of water requiring treatment in municipal stormwater facilities. For example, an EPA study showed that the Congaree Bottomland Hardwood Swamp, near Columbia, South Carolina is capable of removing a quantity of pollutants that is equivalent to what would be removed by a five million dollar waste water treatment plant and the state of Georgia saves one million dollars annually in water pollution abatement due to the presence of a 2,500-acre wetland (EPA-Wetland Functions, 2011).

Recently, the city of Philadelphia's Water Department (PWD) attempted to produce a comprehensive breakdown of ecosystem services and other social, health and environmental benefits that are difficult to quantify. The analysis attempted to justify the return on investment for a 20-year, $1.6 billion green stormwater infrastructure initiative. Analysis by environmental economists placed the total net value of the societal benefits such at $2.2 billion (Philadelphia CSO Plan, 2009). Figure 5.2 shows a breakdown of the benefits.

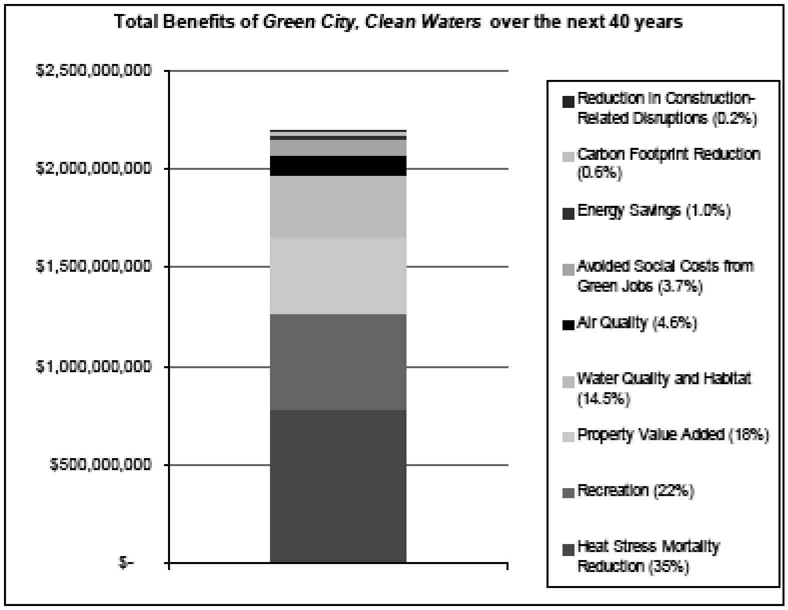

Figure 5.2: An attempt to quantify all aspects of green stormwater infrastructure over a forty year period (Philadelphia CSO Plan, 2009)

LID Principles and Objectives

There is no one single definition of LID that can be applied to all development types (residential, commercial, industrial, and recreational) as scale and design approach ultimately depend on the context of development to which it is applied (Miccio, 2010). Fundamentally, LID is encompassed by a universal set of principles derived from an appreciation of the true capacity of natural systems and a commitment to work within these limits when possible ("Stormwater Strategies", 1999) As a lot-level approach that attempts to match pre-development hydrologic conditions across all ranges of rainfall intensities and durations, LID techniques are based on several basic site design objectives related to maintenance and education, conservation, site planning and minimization techniques, and distributed and integrated management practices.

Maintenance and Education

Promoting core watershed and LID knowledge through effective outreach and education is essential, as is the development of clear and reliable long-term maintenance programs with enforceable guidelines. It is imperative that both the public and professionals are educated and engaged so that LID practices can proliferate through proper maintenance and community support (CITE: Hinman, 2005; “Design Strategies”, 1999; “A New Paradigm”, 2000).

Conservation Measures

LID advocates a reduction in the use of clearing and grading practices and the retention or recreation of as much native vegetation, soil, topographic and natural drainage features as possible. These conservation measures contribute to a site’s ability to effectively utilize natural processes and features within the landscape to manage stormwater naturally by slowing, storing, and infiltrating it (Hinman, 2005; “Design Strategies”, 1999; Shaver, 2000).

Site Planning and Minimization Techniques

It is essential to have early integration of stormwater management during site planning, instead of near the end of the design process where it is more commonly addressed. The approach should be multi-disciplinary, involving land management professions such as planners, landscape architects, engineers and architects. Design measures should be employed in a pro-active approach to management rather than a reactive, or a mitigation-based strategy. A key objective is to not only reduce the total impervious surface area, but also to increase hydrologic disconnects by diminishing areas of contiguous impervious cover. In addition, strategic planning and analysis helps situate buildings and other infrastructure in the most appropriate location, i.e. away from critical areas and soils that provide effective natural infiltration (Hinman, 2005; "Design Strategies", 1999; Shaver, 2000).

Distributed and Integrated Management Practices

Locating various small-scale hydrologic controls allows stormwater to be managed as close to its origin as possible, helping to reduce the reliance on more conventional conveyance and storage techniques while increasing the overall reliability of the stormwater management system. These controls, which promote detention, retention, and infiltration opportunities, can be integrated in to the overall design and featured as an amenity in order to generate multi-functional landscapes (Hinman, 2005; "Design Strategies", 1999; Shaver, 2000). From a technical standpoint, there are four major hydrologically-based elements on which LID design controls should focus: curve number, time of concentration, permanent storage areas (retention) and temporary storage areas (detention).

The first of these, curve number (CN), is an empirical parameter used to estimate the amount of rainfall that will be converted to runoff in a given area. CN is a function of local soil, plant cover, amount of impervious area, interception, and surface storage (USDA TR-55, 1986). Efforts should be made to maintain the predevelopment runoff volume, or minimize the post-development CN through various measures including the reduction of impervious surfaces and the enhancement of interception and detention capabilities through the preservation of trees and natural land cover ("A New Paradigm", 2000).

Time of concentration (TC) is the time it takes for runoff to travel through the watershed. TC is dependent on factors such as surface roughness and slope. In undeveloped areas, the natural vegetation and topographical features retard the velocity of water flowing across its surface (USDA TR-55, 1986). Maintaining predevelopment TC values can be achieved by prescribing certain 'rough' land cover types or by lengthening the flow paths and is an important medium in which the reduction of runoff can be achieved naturally ("A New Paradigm", 2000).

The last two hydrologically-based elements have to do with the ability of a site to intercept and hold water—retention and detention. Retention, or the permanent storage of water on a site, is instrumental in providing both volume and peak control, as well as aiding water quality. Detention provides temporary storage and gradual discharge of water on site and is beneficial in the control of peak runoff rate and may also help prevent flooding (“A New Paradigm”, 2000).

Examples of LID Techniques

As a result of these fundamental principles and systems approach, there exists a multitude of runoff control opportunities within the realm of LID strategies. Also known as integrated management practices, these basic strategies capitalize on the earth’s natural cycles, particularly the hydrologic cycle, in order to assuage

	Runoff prevention	Detention	Retention	Conveyance	Water Quality
Bioretention		x	x		x
Infiltration trench			x		x
Dry wells		x	x		
Roof top storage		x	x		x
Vegetative filter strips				x	x
Rain barrels		x	x		
Swale and small culverts		x		x	x
Swales		x		x	x
Infiltration swale		x	x	x	x
Reduce imperviousness	X				
Strategic clearing/grading	X				
Engineered landscape	X				
Eliminate curb and gutter	X				x
Vegetative buffers	X				x

Table 5.3: Primary functions of various LID techniques (adapted from “A New Paradigm”, 2000)

the impacts of land development on hydrology, water quality, and ecology. They are effective because of the combination of physical, chemical, and biological processes they exploit in order to control water quality, quantity or both ("Stormwater Strategies", 1999). Table 5.3 provides examples of various LID strategies and the breadth of their functions. Examples of several LID techniques are included below:

Bioretention

A strategy that relies on conditioned soils and specific varieties of vegetated material to filter out pollutants from stormwater runoff stored in a shallow depression. It utilizes the physical processes of filtration, the chemical process of adsorption and the biological process of microbial decomposition. There are several design considerations involved with the use of bioretention, some of which include type of plant material, specific maintenance requirements, and the infiltration rate of existing soil ("Design Strategies", 1999). Figure 5.3 is a section view of a general bioretention feature.

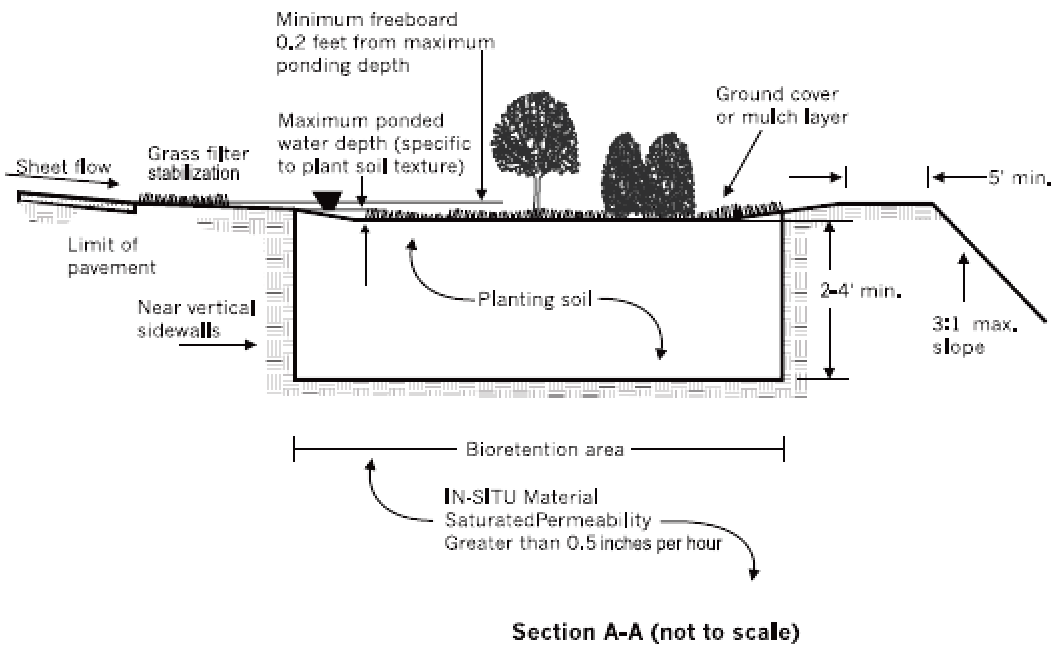

Figure 5.3: Cross-section of a basic bioretention design (source “Design Strategies”, 1999)

Permeable pavements

Most sites require some form of hardscape to support the use and circulation of an area by pedestrians and/or automobiles, such as driveways, parking lots, sidewalks, boat launch ramps, and patios. In fact, two thirds of the impervious surfaces in developed communities are tied to surfaces paved for automobiles (Lake Superior Streams, 2011). There is a collection of LID techniques loosely defined as pervious, porous, or permeable pavements that have significant value in the ability to reduce stormwater runoff. Generally, these pavements all contain a permeable surface on top with a porous media reservoir located directly below it that collectively serves to infiltrate and filter stormwater while

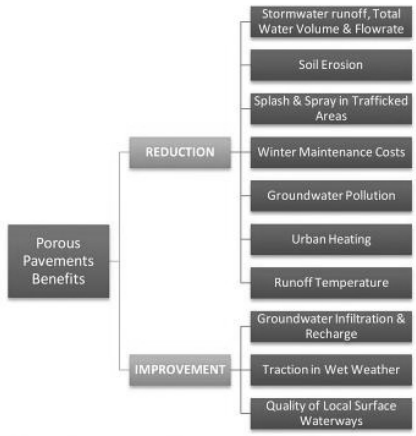

Figure 5.4: Benefits of permeable pavements (source Gopalakrishnan, 2011)

providing a variety of other benefits as illustrated in Figure 5.4 (Gopalakrishnanv, 2011). When properly installed and maintained, pervious pavements have been reported to infiltrate up to 80 percent of annual runoff volume, while also removing up to 95 percent of sediment and 65 to 85 percent of undissolved nutrients (Dauphin County Conservation District, 2011).

Pervious pavements help reduce the need for other stormwater controls because their use is a substitution and not an addition, providing a certain value that other LID techniques do not offer. Not only is the pervious pavement not taking up additional land, but the cost for the pervious paving options are not in addition to the costs of the traditional paving technique, but rather instead. Numerous manufacturers produce a variety of products, including: porous asphalt, pervious concrete, permeable concrete block pavers, turf pavers or even crushed aggregate. One of the biggest concerns with permeable pavements is the maintenance that is required to prevent the filling of the voids, which allow water to penetrate into the ground.

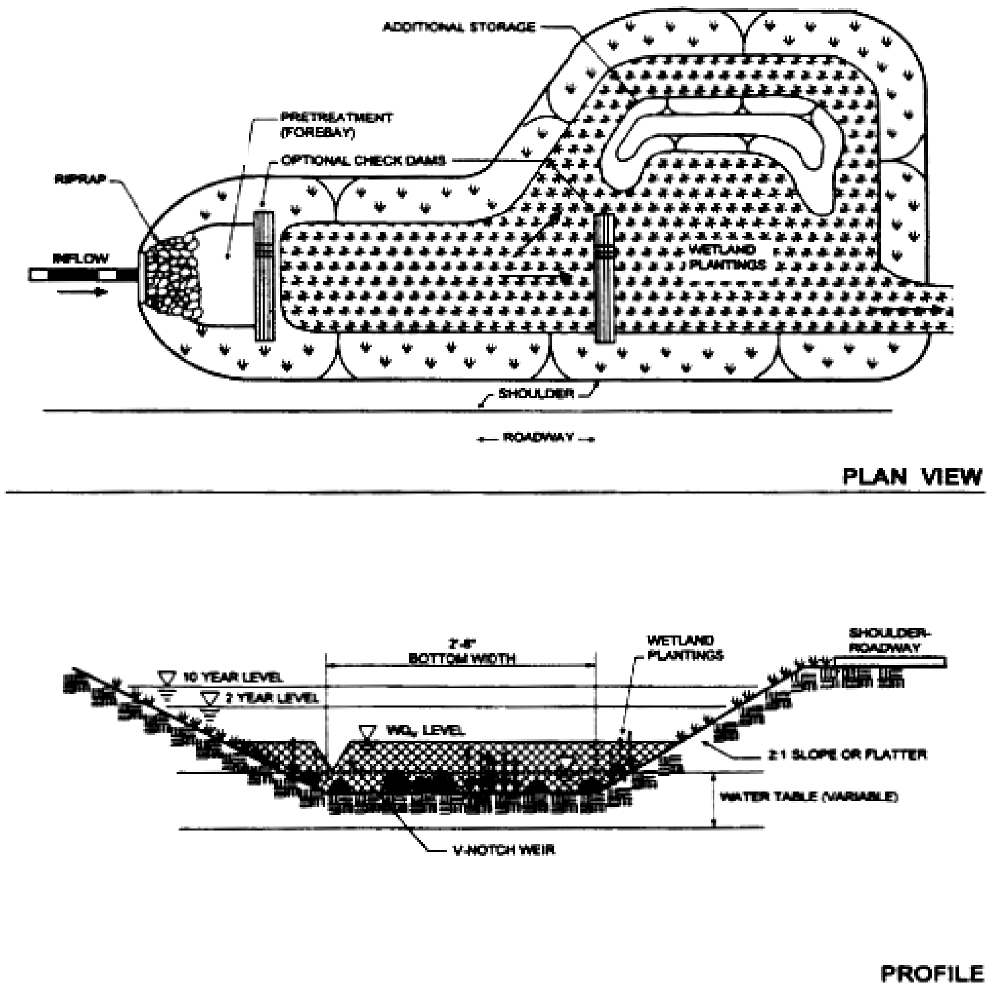

Figure 5.5: Diagrams of a vegetated swale (source “Design Strategies”, 1999)

Vegetated swales

Sometimes referred to as a bioswale, these uncompacted, vegetated and unlined runoff channels convey water at a reduced rate of speed while also providing temporary water storage. Designed with native grasses, shrubs and trees that are either wet or drought tolerant and salt tolerant, bioswales have a high potential for water and pollutant uptake. Due to the linear nature of vegetated swales, they are best incorporated alongside impervious surfaces around buildings, roadways, sidewalks, and parking lots (Watson and Adams, 2011).

Inlet/Filter Systems

Typically a manufactured system, these products are installed in catch basins, or drain inlets, and exclusively provide quality control.

Extended detention basins

Ideal for larger storm events, extended detention basins have dominated stormwater management for decades. Typically designed to hold flows for a minimum of 24 hours, wet and dry detention basins functionally serve to reduce peak flow as well as provide some level of quality improvement. The holding capacity allows for settling, adsorption, and transformation of pollutants, while also reducing outflow to nearby streams to a more manageable rate ("Urban Stormwater Management", 2009).

Below-ground detention/infiltration

These cisterns reduce stormwater volume by capturing and storing rainwater that has infiltrated from a permeable surface such as pervious pavement or a bioretention area. Although there is no water quality improvement, the stormwater can be reused for various non-potable needs such as irrigation and flushing of toilets and the sub-surface location results in the minimal consumption of land.

Engineered wetlands

A complex biological system, wetlands are extremely valuable for their ability to clean both air and water, while also providing detention and an ideal habitat for birds and amphibians. Important design considerations include proper drainage which promotes optimized hydraulic behavior, water quality improvement, and biodiversity increase (Watson and Adams, 2011).

Figure 5.6: An engineered wetland constructed in a former gravel pit (source Watson and Adams, 2011)

Open-space and buffers

These are two rather practical LID strategies that alleviate some of the impacts of stormwater runoff by providing opportunities for infiltration and filtration through the use of natural or planted areas (“Design Strategies,” 1999). In addition to hydrologic benefits, preserving buffers and open-space create opportunities for wildlife corridors for both animals and plants (Watson and Adams, 2011).

These are just a sample of the numerous LID practices that are changing the way stormwater management is practiced. A variety of factors will dictate which is the most appropriate for a given site, such as the size of the watershed, the soil type, the overall imperviousness of the watershed, the pollutant of greatest concern, and both the amount of land and price of land (Wossink and Hunt, 2003).

LID offers almost endless opportunities for managing stormwater sustainably and provides a host of environmental, economic, and social benefits that do not exist with conventional stormwater management. This green infrastructure-based approach to stormwater management seems like a viable alternative to conventional approaches; however, there are a significant number of barriers that have prevented it from being uniformly accepted and implemented in many towns.

CHAPTER SIX

BARRIERS TO LOW IMPACT DEVELOPMENT

As with any new concept or initiative, there is often significant resistance that must be overcome. With Low Impact Development, there are considerable barriers, both real and perceived, that have prevented the widespread implementation of these techniques nationwide. Many of these barriers can be attributed to the flexible and decentralized nature of LID, as traditionally stormwater has been managed centrally by government. The scope of LID obstacles span from financial to educational to political, yet need to be clearly understood so that LID may be incorporated into these systems and become a more mainstream practice.

Financial Barriers

Financial uncertainties abound with LID; questions of cost efficacy exist in the full life cycle from design and construction to operation and maintenance. Total cost and profit margins are of vast importance with any business and the reality is that the ‘bottom line’ is often the driving force behind many development projects. Unfortunately, there is a lack of readily accessible cost analysis information to support LID, which is counter-productive to creating real change, especially in a weakened economy. Oftentimes universities can be a great source of all kinds of LID data; for example Table 6.1 is the result of LID research performed at North Carolina State University, comparing the comprehensive costs of LID techniques.

Practice	Wet pond	Wetland	Bioretention in clay soils	Bioretention in sandy soils
Construction cost	65,357	11,740	124,445	7,843
Annual maintenance cost	4,411	752	583	583
Opportunity cost of land ($217,800/acre)	43,560	65,340	65,340	65,340
Present value of total cost	146,474	83,486	194,751	78,137
Annualized cost per acre watershed	1,721	981	2,288	918
Annualized cost per percent pollutant removed				
• TSS	26	15	N/A	N/A
• TN	61	45	51	20

Table 6.1: A comparison of costs for four LID treatments in a ten acre watershed (CN 80) (source Wossink and Hunt, 2003)

In 2005, the city of Olympia, Washington, which is located in the Puget sound, a sensitive estuary in the Pacific Ocean, produced a memorandum rationalizing the use of pervious pavements in city-funded sidewalks. This memo was based on a thorough study that analyzed construction and maintenance costs and revealed that pervious sidewalks, at $54 per square yard, were a more cost effective option than traditional sidewalks, at $101 per square yard ("Green Infrastructure," 2010). One of the critical financial barriers to LID revolves around alternative funding sources and incentives. Incentives such as tax credits and impact fees could not only alleviate stormwater management concerns and facilitate water quality improvements, but also spur some momentum in the development community. For example the City of Portland, Oregon offers a bonus program to developers that allows for an increase in buildable area in exchange for the construction of an ecoroof. This incentive program has been instrumental in the creation of more than 120 ecoroofs in the city, as well as over $225 million in additional private development ("Green Infrastructure", 2010) Residential homeowners can also be targeted with incentives to help change behaviors that ultimately impact stormwater. From 1993 to 2011, Portland also offered an incentive to utility customers for simply disconnecting downspouts and redirecting the water to a pervious surface. Over 56,000 downspouts were disconnected, removing 1.3-billion gallons of stormwater annually from the city's combined sewer system (Downspout Disconnection Program, 2011).

While the financial costs for utilizing LID in new developments may be comparable with conventional techniques, the process of retrofitting existing properties can be expensive. Typically, prices can be expected to decrease as these alternatives gain recognition, but early implementers usually pay a premium (Valentine, 2007). Some of the pricier technologies are often lowered after a pilot phase. The City of Chicago has a Green Alley Program which retrofitted over 3,500 acres of asphalt and concrete in alleyways throughout the city with pervious pavement ("Green Infrastructure", 2010). In its first pilot year, the cost were 150-200 percent more than conventional alley retrofits, however today the costs are now comparable to the costs for traditional material approach ("Green infrastructure", 2010).

The familiar phrase 'time is money' highlights another important barrier to the adoption of LID technologies. Implementation of any non-standard practice naturally takes more time. More time is often required in the design phase in order to customize the LID approaches to individual sites and for those unfamiliar with the process, the added expense of outside design help is much more expensive than just utilizing conventional technologies. In addition, delays with the permitting and approval process are often unavoidable when building 'outside of common code'. Combined, these delays in design and permitting can wreak financial havoc on a project ("Stormwater Solutions", 2007).

Political Barriers

Along with financial barriers, there are federal, state and local political encumbrances that pose an obstacle for Low Impact Development; the numerous political encumbrances associated with it. Much of our existing land development policy and code was crafted in the early 1900s. As such, over the past 100 years those policies and codes have been put in place in every state and city in the United States. Unfortunately, those somewhat outdated laws do not easily allow for the incorporation of green infrastructure practices. Often there are rules that directly or indirectly prevent the use of innovative LID techniques. These rules include subdivision codes, zoning regulations, parking and street standards and other local ordinances that determine how development happens (Center for Watershed Protection, 1998).

These automotive-oriented standards focus on street width, parking requirements, and fire codes making it difficult to implement new low-impact approaches such as narrower roads, open drainage and cluster development techniques. If these local policies regarding street design, landscaping and parking were rewritten to complement stormwater standards, developers would be able to simultaneously meet multiple requirements ("Green Infrastructure", 2010).

Changing existing policies can be difficult and time consuming. Code review can be quite an extensive process which requires substantial effort and coordination. Although many jurisdictions have begun to tackle the task of revising and updating codes to remove barriers, most have not. Likely, this is due to a lack of physical resources; often there is simply insufficient staff and time to accomplish this charge ("Stormwater Solutions", 2007). Along with the lack of financial and technical resources, many cities are finding that the federal government is inhibiting change. The EPA has been criticized for promoting innovative alternatives without actually making any changes to water quality standards and cities are often hesitant to make any financial reallocations for green infrastructure related projects without better guidance and the assurance that investments will be supported by federal regulatory measures (“Green Infrastructure”, 2010).

From a developer’s perspective, not only are the state and local policies limiting, but their approval process are often full of redundant, unclear and conflicting requirements. Due to the decentralized nature of green infrastructure, redundant requirements can be costly; a typical example is when local government mandates conventional stormwater systems to be installed in addition to the use of LID technology (“Stormwater Solutions”, 2007). In an attempt to streamline their review process, the city of Philadelphia partnered with developers to form a Developer Services Committee. The outcome of this collaboration was a streamlined process for permit review, inspection, and approval. Changes central to the improved review process required concept approval for water, sewer, and stormwater prior to zoning permit approval (“Green Infrastructure”, 2010).

There can be tremendous discontinuity when multiple government entities are involved. Requirements may vary from project to project or between different jurisdictions and answers to questions may vary depending on the staff member being questioned. Sometimes developers are expected to comply with the requirements of multiple political jurisdictions within a region, which can seriously compound the issue (“Stormwater Solutions”, 2007). Agencies and departments within and across various levels of government may have conflicting objectives and requirements. Not only can this create serious delays with the approval process, but it can contradict any attempt at promoting green infrastructure through stormwater regulations. A Green Urban Design process was initiated by Chicago’s Department of Environment and involved the review of ordinances across eight city agencies, isolating incompatible ordinances and developing a framework to rectify the inconsistencies (“Green Infrastructure”, 2010) Even the EPA has acknowledged that increased coordination between entities such as the National EPA Program offices, Regional EPA offices and the Office of Enforcement and Compliance Assurance would be instrumental in removing inconsistencies in polices, permits and enforcement orders (“Green Infrastructure”, 2010).

Often it is not so much about government and policy inhibiting LID, but rather it is more an absence of government support, encouragement and leading by example. Sometimes all that is missing from the political arena is simply a strong leader with an environmental ethos to advance and support the technology. Several large US cities, including Seattle, Philadelphia, and Chicago recently embarked on green infrastructure projects and partnerships despite many of the other barriers. The common element amongst these cities was its leadership and not relying on a strict cost-benefit analysis (Valentine, 2007). Other times, what is necessary is a clearly articulated requirement. Regulations that require specific, measurable stormwater standards are surfacing in cities as a viable mechanism for promoting LID. In an attempt to better manage existing infrastructure assets and to avoid future operations and maintenance costs, the Philadelphia Water Department implemented green infrastructure policies, including a stormwater standard which requires the first inch of water to be retained on site. After one year, this single regulation resulted in the redevelopment of a total of one square mile of impervious cover and a reduction of combined sewer overflow (CSO) inputs by a quarter billion gallons. This translates into a cost-savings for the city in the range of $170 million ("Green Infrastructure," 2010).

Although this stormwater regulation has proved to be extremely valuable to Philadelphia and many other cities, the reality is that the impact of stormwater regulations often only extends to properties seeking new permits, which does not account for most land use types or for properties that are grandfathered in to older, less environmentally protective requirements. In fact, research by the city of Philadelphia has discovered that stormwater regulations alone would only effectively target 20 percent of impervious surfaces; further that 20 percent would only be impacted after new regulations had been in place for 20 years. Figure 6.1 illustrates the scope of policy issues that need to be addressed.

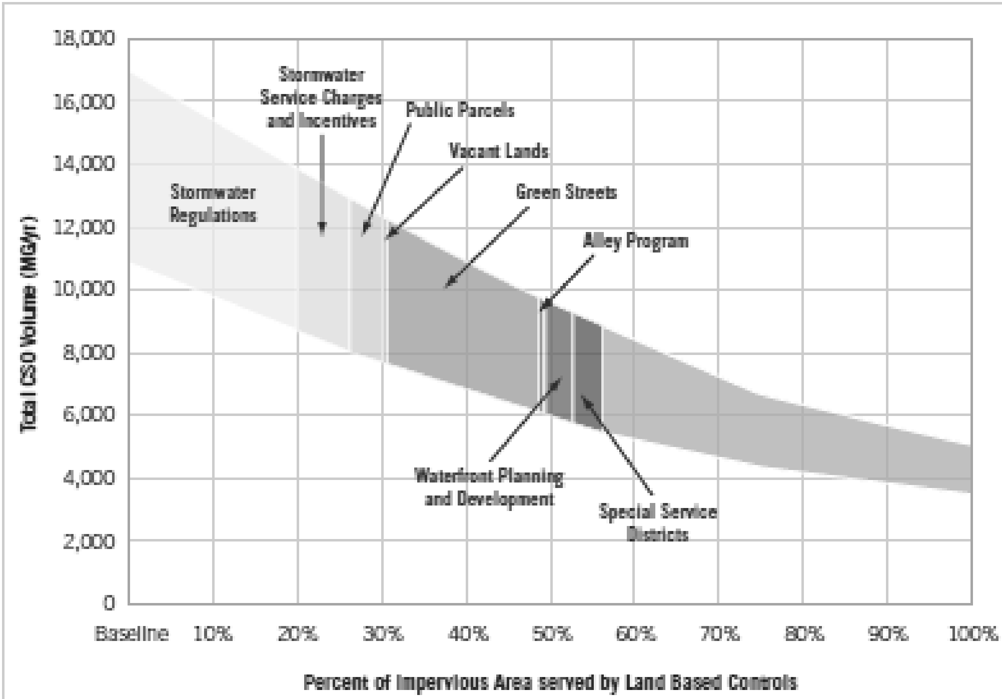

Figure 6.1: A chart displaying how much certain city-related entities are potentially contributing to impervious area in the city of Philadelphia (source "Green Infrastructure", 2010)

Areas requiring additional policy consideration include vacant properties, public land, streets, and waterfront areas ("Green Infrastructure," 2010). These types of properties can account for a significant amount of land and potentially a significant amount of impervious surfaces in a region. For example, vacant properties are unmaintained land that likely has minimal functioning stormwater controls and may be full of impervious surfaces or compacted land. In addition, they can sometimes become used as illegal dumping grounds. Streets are a highly regulated entity with predominant concerns surrounding functionality, efficiency, and safety. They create miles of impervious surfaces, yet at the same time often have open land surrounding them which could be valuable for treating roadway runoff. Reassessing the regulations surrounding these types of land in order to make greater accountability for a site’s stormwater ‘footprint’ could contribute to supporting LID usage.

Physical Barriers

Realistically, not all sites are suitable for LID; appropriateness is dependent on several site specific factors including slope, soil permeability, and depth of water table (EPA-LID Literature Review, 2000). These factors can influence the movement of water through a site, ultimately impacting the potential effectiveness of LID, for instance a high water table poses the risk of increased potential for groundwater contamination (“Stormwater Solutions”,2007). In addition to these site specific challenges, LID techniques compete for valuable open space. Whereas conventional stormwater infrastructure is often located underground, LID applications typically require some surface land area where stormwater collects and infiltrates. This physical space requirement can be challenging to developers working with new developments or retrofits. Developers are often required to meet specific density requirements and are likely focused on maximizing buildable land in order to maximize profits. The use of LID techniques in the public realm presents a similar space constraint. Multiple demands in the right-of-way such as sidewalks, bike lanes, parking, utilities, stormwater infrastructure and traffic lanes limit the available space and impedes the placement of LID applications along the street (“Stormwater

Solutions", 2007). Again, Emeryville, California is a great example of a town that refused to be limited by site-specific obstacles. Formerly an industrial hub, the city was not only on the decline, it was haunted with an abundance of contaminated properties from its past. Using a Smart Growth grant from the EPA, the town designed a customized and comprehensive set of stormwater policies and guidelines in an effort to promote more sustainable solutions to the brownfield dilemma. Guidelines addressed specific constraints faced by the city, such as heavily urbanized sites, compacted and contaminated soils, and a high ground water table.

Scientific Barriers

Conventional stormwater practices have been refined over the past 50 years with volumes of associated performance data that establish its ability to effectively contain and treat stormwater runoff and these practices are easily validated through stormwater modeling software. Conversely, the lack of similar stormwater modeling capabilities and available technical data to support the effectiveness of Low Impact Development in different environments presents itself as a serious impediment to LIDs universal acceptance.

Calculations and statistics that demonstrate consistent performance of LID techniques are insufficient or lacking, as a result of the length of time necessary to show long-term performance and limitations in common data collection methods ("Green Infrastructure", 2010). Again, universities can be a great resource, providing regionally applicable data; for example Table 6.2 shows the median pollutant removal effectiveness for several pollutants affected by four specific LID treatments.

BMP type	*TSS*		*TP*		*NO_3^-*		*TN*		*Zn*	
	Rmvl. Effic. (%)	*No. Sites*	*Rmvl. Effic. (%)*	*No. Sites*	*Rmvl. Effic. (%)*	*No. Sites*	*Rmvl. Effic. (%)*	*No. Sites*	*Rmvl. Effic. (%)*	*No. Sites*
Wet ponds	65	27	46	28	42.5	16	28	27	51	24
Stormwater wetlands	61	14	32.5	14	55	8	22	14	49	6
Sand filters	79	12	59	11	(56.5)	11	41	12	64	11
Bioretention areas	N/A	—	71	5	16	4	45	4	89	4

Table 6.2: Median pollutant removal effectiveness for four LID treatments, or Best Management Practices (Wossink and Hunt, 2003)

Despite having a considerable understanding of individual LID practices, significant gaps exist regarding how these techniques and practices function within a system. There is a lack of ability to demonstrate that LID is a comprehensive management approach that works at both a small and large scale (Kearns and McNew, 2002). The decentralized and flexible nature of Low Impact Development creates challenges with conventional stormwater modeling approaches in representing the effectiveness of these applications. It is difficult to redesign existing stormwater models to allow for “micro-scale” modeling of small areas such as gardens and driveways and smaller storm events over multiple years (BMP Modeling Concepts, 2006).

Further data issues arise as a result of green infrastructure's emphasis on stormwater management through natural systems which can be highly variable depending on site specific characteristics such as climate, soil, topography, and geology. For that reason, the most effective and reliable data for a given region may be garnered through local pilot projects endeavors (Valentine 2007). For instance, the University of New Hampshire undertook a two year study to evaluate the effectiveness of various LID treatments in cold climate conditions. Results indicated that the functionality of several of the treatments remained high during winter months, while others showed signs of seasonal performance variation (Roseen et al, 2009).

Presently, there are a large number of green infrastructure demonstration projects across the U.S. actively monitoring performance related to retention volume, flow reduction, and pollutant removal; however, until sufficient data exists that can demonstrate green infrastructure provides quantifiable and cost effective alternatives to conventional stormwater management, government agencies will likely remain opposed to investing significant resources into these alternative solutions and instead rely on "tried-and-true" conventional approaches.

Educational Barriers

Lack of understanding is an underlying issue for the minimal advancement of many progressive movements, green infrastructure included. Repeatedly, the importance of educating individuals emerges as essential to the successful implementation of LID. The broad spectrum of key individuals to educate includes property owners, government officials, developers, contractors, architects, planners, etc. Not knowing or inaccurate understanding of LID approaches to stormwater management has been identified as a significant barrier (Roy et al, 2008). There is concern among development professionals that many of their colleagues have limited knowledge of LID principles, and are therefore unfamiliar with design, construction and maintenance of these techniques ("Barriers and Opportunities", 2008). Architects, landscape architects, planners and engineers are commonly relied upon to provide guidance in the form of professional expertise and therefore can be instrumental in shaping a project. Without a deep understanding of LID principles, it would be very difficult to confidently advocate for and convince project owners to stray from conventional approaches.

Public awareness and dissemination of information to individuals has been acknowledged as an important component in the development of public opinion and support towards sustainable stormwater management approaches

(Apostolaki& Wild, 2006). Unfortunately, many Americans believe the construct of the ‘American suburban dream’ consisting of a large lot and wide streets. Any reduction of these features is perceived to be undesirable and even unsafe, although this may not be factually true. Furthermore, there are others who are under the impression that if conventional stormwater controls are removed, they will be subjected to flooding issues (EPA-LID Literature Review, 2000). Additional challenges lie in the public’s inability to identify the most fundamental issues relating to stormwater and water quality. Most people do not comprehend that runoff which has flowed across roads, parking lots, farm fields, lawns, and other surfaces is the leading cause of water pollution in the U.S; most believe industrial sites are still to blame. Today, however, the individual’s environmental footprint has become more significant and of greater concern (Coyle, 2005).

Despite identifying clean water as a top priority, most Americans fail to recognize that the combined daily actions of themselves and their neighbors have a considerable impact on water quality (Coyle, 2005). Seemingly basic tasks including car washing, lawn fertilization and picking up after pets can have serious implications for water quality. Unfortunately, environmental issues often have extended lag times, or “attenuated causation”; this makes the connection between personal actions and consequences difficult to recognize (Kollmuss and Agyeman 2002, cited by Coyle, 2005).

Gwinnett County in Atlanta, Georgia has devised a creative way to combine economic incentives with education. The county's Department of Water Resources (DWR) has implemented a Stormwater Credits Program which is available to homeowners, business owners, developers, designers, builders, municipal officials and other property owners within the community. Participants can receive a credit on their stormwater utility fee in exchange for performing certain activities that will help promote improved water quality and reduce costs for the DWR.

Four different categories of credit exist in the rebate program. Three of the four are related to specific property improvements that will influence water quality, quantity, and flow, with a ten percent maximum allowable credit for each of the three categories. The fourth option, watershed stewardship, provides up to a 40 percent credit for those property owners that take action to protect the watershed or make a concerted effort to educate themselves, or promote public awareness on watershed management. Public participation options include becoming certified as an Adopt-a-Stream volunteer, spending time stenciling stormwater drains, and participating in stream clean-ups. The county also offers free training programs to all property owners in exchange for stormwater credits.

In addition, educational institutions and child care centers that provide or promote educational activities that complement the county's stormwater goals are eligible for credits as well. Three categories of credit exist for these types of institutions, Watershed Education Curriculum, Watershed Education Stewardship Activities, and participation in academic field studies or classes at the local Environmental and Heritage Center (Gwinnett Stormwater Credits Manual, 2011).

Maintenance and Operational Barriers

Clear lines of funding, control, and accountability have been established with conventional, centralized stormwater management systems. Typically, the management systems are controlled by a legal entity such as a Water or Sanitary District. These Districts, which are charged specifically with treating wastewater and controlling flooding, are themselves regulated by state and federal laws and are responsible for both operation and maintenance of conventional stormwater systems (Valentine, 2007). Functionally, the decentralized and flexible nature of green infrastructure is powerful, but operationally, it can be limiting.

Maintenance is a necessity with any type of stormwater management, but the use of green infrastructure techniques can sometimes create a more complex scenario. As a result of its decentralized nature, LID treatments are commonly located on private property, which can present a challenge to public works departments. Public officials are concerned with ensuring that a stormwater treatment is properly maintained, so that it is remains a viable and effective component of the intricate stormwater management system. Often the initial year or so of maintenance is not the problem, but rather the practicality and enforcement of a long term plan. Maintenance requirements will vary depending on the specific application; some of the common needs include mowing or trimming of vegetated features, replacing dead or diseased plants, replacing of soil every five to ten years, re-mulching, and removal of accumulated sediment (EPA-LID Literature Review, 2000). The responsibility and cost for maintaining LID treatments lies with the property owner. In public projects, this specialized maintenance can often be a deterrent to the project's approval and in private projects, enforcement of maintenance responsibilities can be difficult. Again, the city of Emeryville, California is recognized for its efforts at addressing the entire lifespan of green infrastructure stormwater treatment systems. Permitting regulations require that developers of any lot 10,000 square feet or larger enter into an operations and maintenance agreement with the City. As part of the agreement, Emeryville requires a bond or a deposit to help guarantee maintenance continues for five years post-construction (City of Emeryville Planning and Building Department, 2007).

With the sizable number of barriers that exist for Low Impact Development, there is an obvious need for collaborative initiatives that focus on providing practical means for combating the obstacles. A great example of this on a local scale is the Southeast Michigan Council of Governments (SEMCOG), which has created an online database of local LID case studies to serve as a reference for communities interested in implementing various LID techniques. The site provides detailed info about the projects, such as costs, impediments, and maintenance activities and responsibilities. A larger scale effort by the American Society of Landscape Architects, started around 2007, is the Sustainable Sites Initiative (SSI), which is similar to the United States Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED). Instead of concentrating on the building as in the LEED programs, SSI provides guidelines and performance benchmarks for sustainable land design, construction and maintenance practices. Not only will this initiative be valuable for the wealth of technical information that will be available in its reference manual, but programs like this have the ability to give traction to a movement by spurring the professional and academic community to seek new means for overcoming existing challenges.

CHAPTER SEVEN

LID IN THE BCD REGION

Although the concept of LID is still a relative newcomer to the ‘tried and true’ world of stormwater management, there are many areas of the country that have embraced the movement completely and this is evidenced by the incorporation of LID techniques and philosophies at all scales of development. To fully comprehend the need and potential impact of LID on the hydrologic system of the BCD region, it was necessary to study the metro regional context.

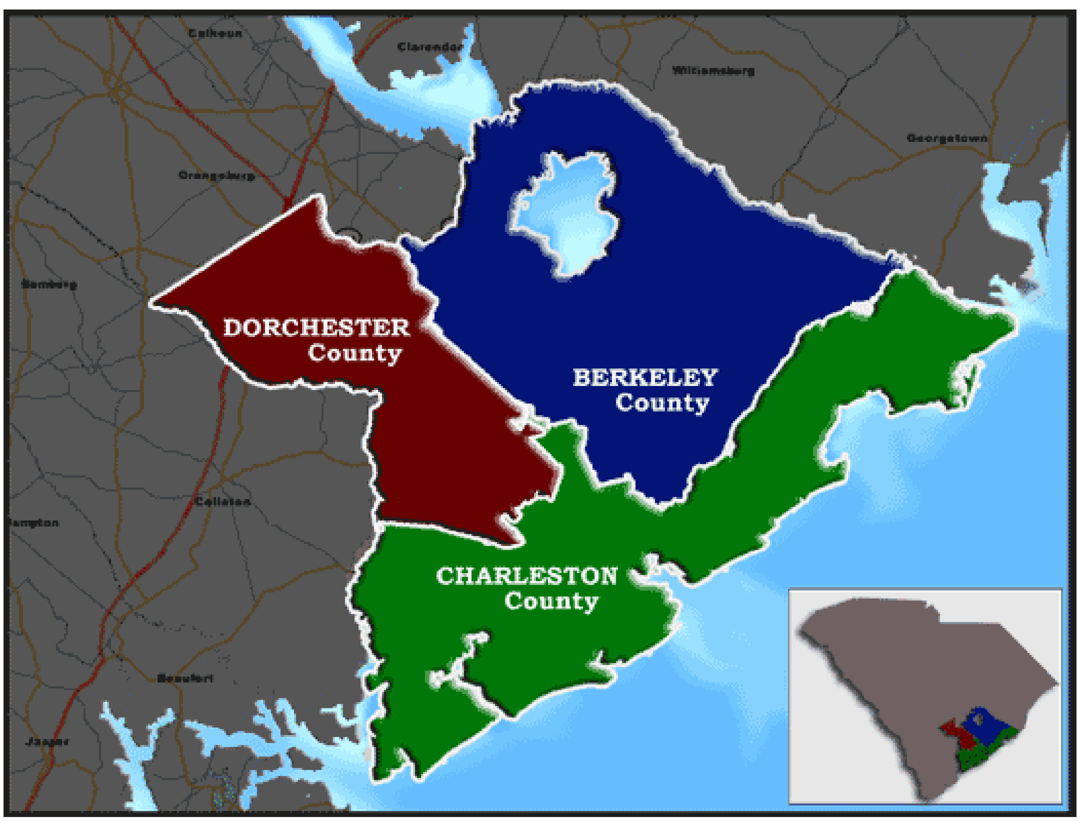

Figure 7.1: The coastal Berkeley Charleston Dorchester (BCD) region of South Carolina (Jackson Appraisal Service, accessed August, 2011)

Existing Conditions

For the purpose of this study, the Charleston metropolitan region is comprised of three counties: Berkeley, Charleston, and Dorchester (BCD). Combined, these three counties have a land area of 2,614 square miles and 91 miles of coastline along the Atlantic Ocean (BCDOG Plan, 2000). This part of South Carolina falls within the Atlantic Coastal Plain region, reference Figure 7.2. By definition, a coastal plain is ‘an area of flat, low-lying land adjacent to a seacoast separated from the interior by other features (Cappiella et al, 2010).

Figure 7.2: The U.S. Coastal Atlantic Plain Province (Cappiella et al, 2010)

BCD counties are part of two major drainage basins, the Saluda-Edisto and the Catawba-Santee. Each of these basins is very large and has been subdivided into smaller sub-basins. The BCD region is part of three sub-basins: the Edisto, Santee, and Ashley-Cooper. Each sub-basin is further divided into over 50 watersheds; the municipal boundary of Berkeley County crosses five, while both

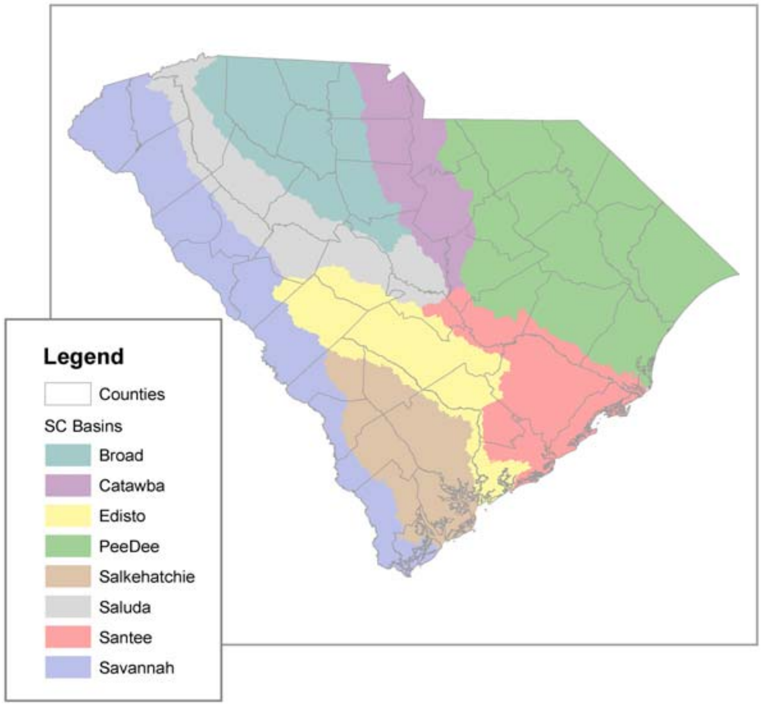

FIGURE 7.3: The eight major river basins in South Carolina (www.SCDHEC.gov, accessed August, 2011)

Charleston County and Dorchester County cross four watersheds (EPA-Surf Your Watershed, 2011). Watersheds of this coastal plain region have unique characteristics and management concerns. In addition to the lack of topography, the groundwater table is high in this region which results in an increased interaction between surface water and groundwater. This combination can have implications on the transport and removal of pollutants. The BCD region is centrally located within an area of South Carolina commonly referred to as the 'lowcountry,' which identifies specific physiographical and cultural traits inherent to the area. As the name suggests, the 'lowcountry' has very little terrain change; elevations range from mean sea level to slightly over 100 feet, with only a few areas with grades of six percent (BCD Plan, 2000). This lack of elevation can be problematic for wastewater and stormwater drainage which often rely on gravity flow systems (Cappiella et al, 2010).

Precipitation in the coastal plain region is rather significant; it is second only to the Pacific Northwest for highest average annual rainfall in the U.S. Within the temperate and humid climate of the BCD region, there is no significant dry season and roughly forty-one percent of the 49 inches of precipitation that falls annually occurs during the summer months. Brief but intense thunderstorms are very common during the summer, producing relatively short durations of concentrated runoff. This type of rainfall event produces a significant spike in the nonpoint pollutant loadings found in adjacent surface waters (BCD Plan, 2000). Unfortunately, the region is also subject to tropical storms and hurricanes.

Soils found in the coastal plain are generally very sandy or poorly drained. In the BCD region, soils vary from well drained sandy loams to muck lands (BCD Plan, 2000). Closest to the coast line, soils tend to be sandy and as a result are extremely permeable. Infiltration rates for these soils can exceed four inches per hour or even more. High rates of infiltration are a benefit when it comes to infiltrating stormwater runoff and promoting groundwater recharge; however, they also increase the potential of groundwater contamination, as pollutants in rapidly infiltrating water have less time to be filtered out by the soil (Capiella et al, 2010).

Unfortunately, poorly drained regions have been subject to extensive ditching over the past 300 years in order to make the land more suitable for agricultural use, as well as for the purpose of controlling floods and the mosquito population. Consequently, the network of headwater streams in the watershed of many regions in the coastal plain no longer exists as a natural system. Many of the zero, first, and second order streams have been replaced with ditches, canals and road drainage.

Despite the decline in the use of ditches for drainage, current land development practices still engage in significant modification of the natural topography to create better drainage. These drastic alterations contribute to downstream flooding and water quality issues (Capiella et al, 2010). Due to the combined effects of soil type, level topography and a humid climate, there are large areas within the BCD region where the soils are saturated with water for a good part of the year. These wetlands, fresh water swamps and tidal marshes often function as natural 'greenbelts', which divide the region into various localities (BCD Plan, 2000).

Collectively, these attributes create a setting that is ripe for frequent or even catastrophic flooding. Within Charleston County, approximately ninety percent of the land contains soils which pose moderate to severe limitations for urban land uses. Developing this land requires additional expense to provide both adequate drainage facilities and necessary protection of wetlands.

Population and Growth

According to the 2010 Census, the population in the state of South Carolina increased by fifteen percent since 2000 to 4.63 million; a larger increase than in most states. Within the BCD region, the population is 631,484, or just under fourteen percent of the state's total population. Between 1960 and 1990 the population of this tri-county region doubled (United States Census Bureau, 1990). From 1990 to 2000, the population of Charleston County increased by five percent (United States Census Bureau, 2000), while from 2000-2010 the population increased by thirteen percent, even with this increased growth, the county was one of ten counties that grew less than the state as a whole (United States Census Bureau, 2010). At the same time the county increased by thirteen percent, Charleston, the second largest city in the state, with a population of 20,083 grew by 24 percent, more than the Census Bureau had estimated. In comparison the largest city in South Carolina, the capital of Columbia, experienced only an eleven percent growth rate. North Charleston, the third largest city in the state, experienced a growth rate of 22 percent, giving it a total

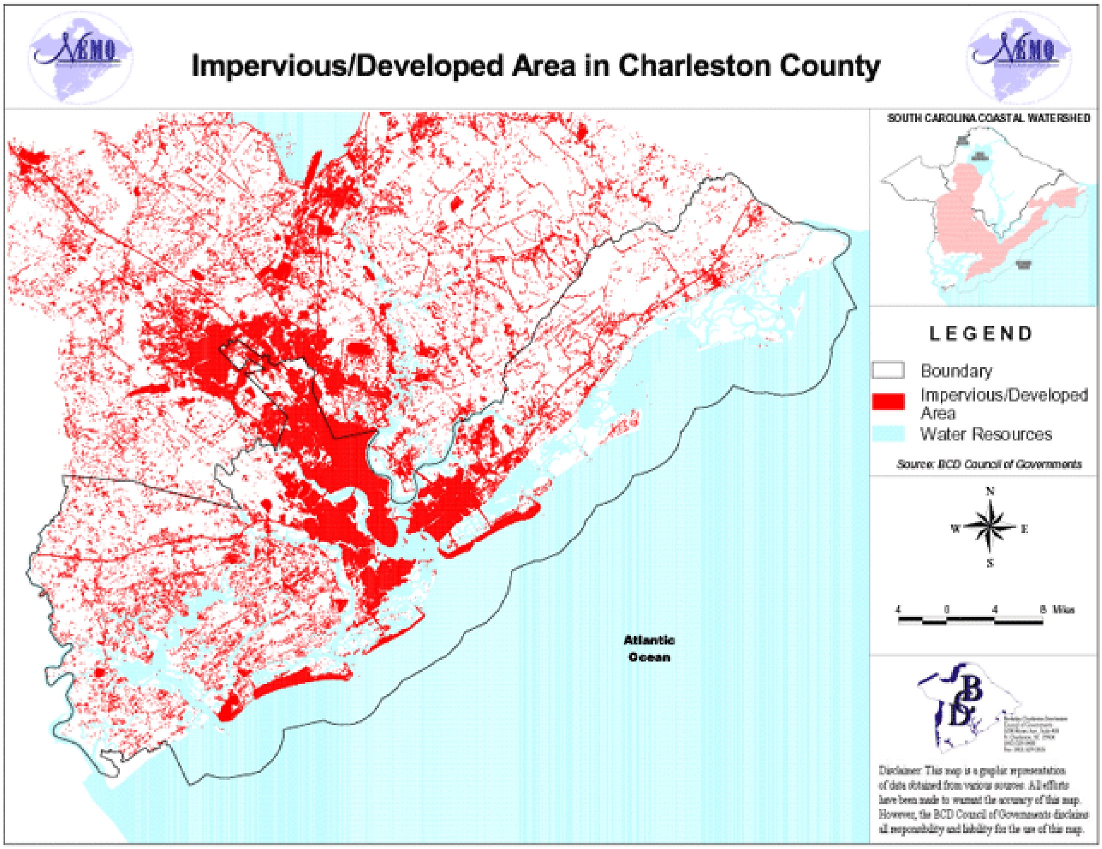

FIGURE 7.4: A geographic representation of developed/impervious areas in Charleston County. The areas of greatest development are centrally located in the regions immediately adjacent to the peninsula of Charleston (source SCNEMO).

population of 97,471. The most rapid growth in Charleston County was in the town of Mount Pleasant, which expanded by 43 percent, making it the fourth largest city in the state with a total population of 67,843 (Behre and Slade, 2011). With 918 square miles and a density of 381.3, Charleston County ranked third in density in the 2000 Census (SC Statistical Abstract, 2011) and is more than twice as dense as Berkeley County.

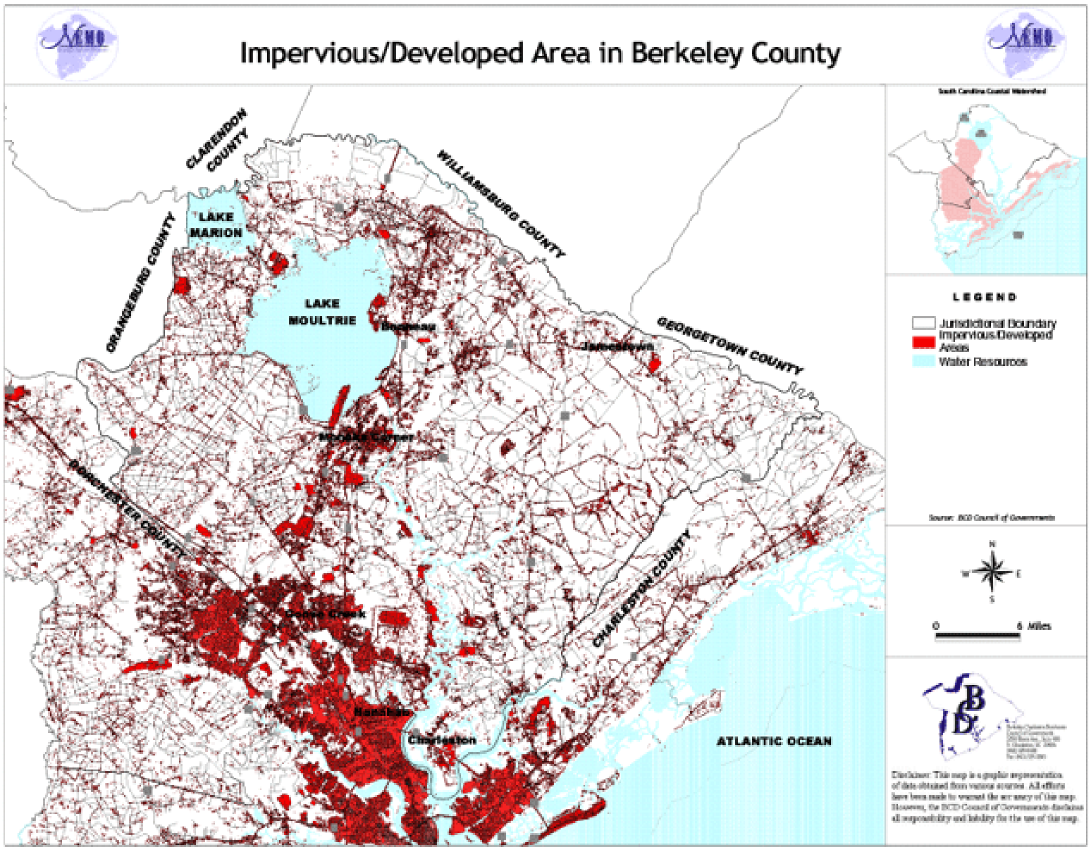

FIGURE 7.5: A geographic representation of developed/impervious areas in Berkeley County. There is much less developed/impervious area, due to federal ownership of thirty percent of the land, which is reflective of its lower population density (source SCNEMO).

Berkeley County, which is the largest of the three counties in land area, has a population of 163,328 (US Census Bureau, 2010). With 1,097 square miles of land, it has a density of 162 residents per square mile (US Census Bureau, 2010) and as of the 2000 Census, ranks as the 17th most dense county in the state (SC Statistical Abstract, 2011). In comparison, the overall density of the state of South Carolina is 153.6 per square mile. Thirty percent of the land mass in Berkeley is federally owned, whereas in the United States, 26 percent of the total land mass is federally owned (BCD Plan, 2000). Obviously, the size of the public land holdings limits the amount of development in Berkeley County and has likely contributed to the increased density of the other two counties of this region.

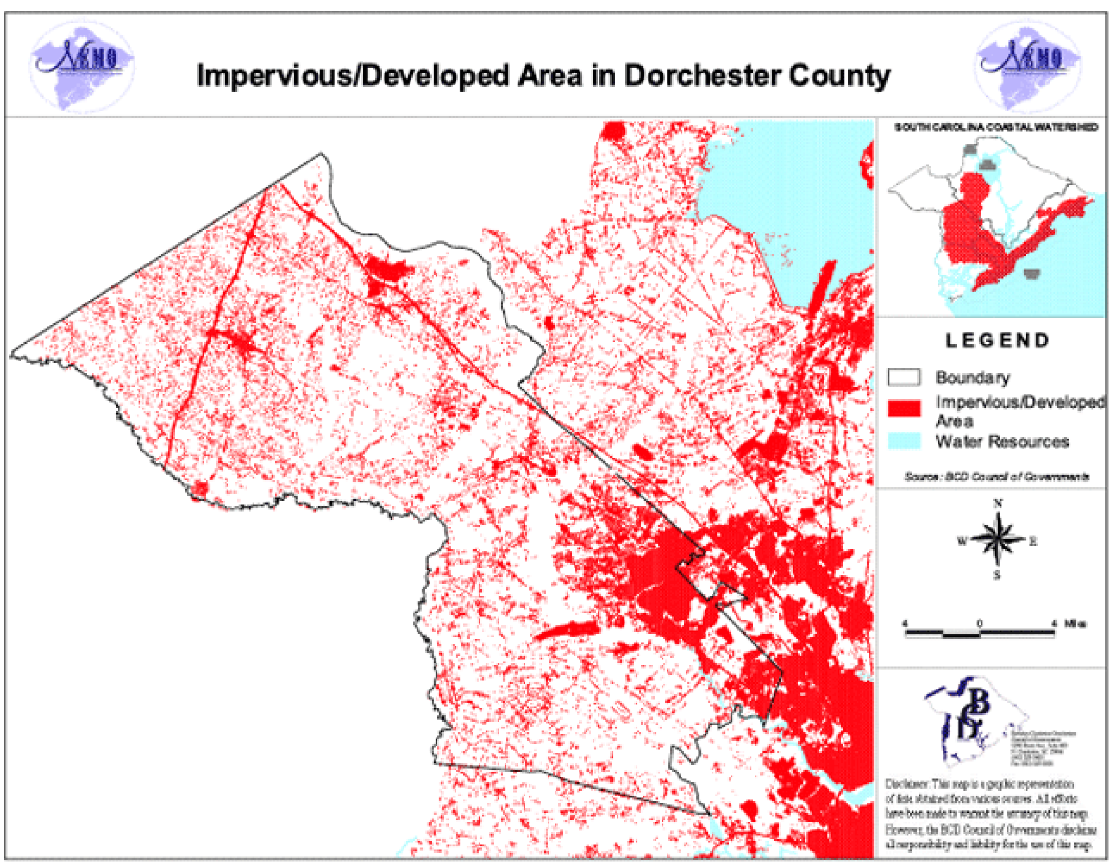

FIGURE 7.6: A geographic representation of developed/impervious areas in Dorchester County. The area of greatest concentration (darkest red), inside the black county boundary, is around the town of Summerville (source SCNEMO)

The smallest land area of the three BCD counties, Dorchester County has grown faster than all counties in the state since 2000 at a rate of forty-one percent. With 574 square miles and a population of 136,555, Dorchester county has a density of 237.6 (US Census Bureau, 2010), ranking as the 11^{th} most dense South Carolina county in the 2000 Census (SC Statistical Abstract, 2011). Much of this growth can be attributed to the abundance of new neighborhoods developed in and around the town of Summerville, which with a 56 percent increase, was the fastest growing of all the state's large and medium-size municipalities. Today, Summerville has a population of 43,392 residents (Behre and Slade, 2011).

Population growth helps contribute to the perception that the Lowcountry is an appealing area in which to reside, which likely perpetuates population growth. This growth, although essential to a strong economy, has the potential to threaten many beaches, marshes, rivers, and creeks that probably attracted new residents in the first place. These natural resources are not only an important cultural identifier and growth medium, but also provide a significant component of the local economy through tourism, recreation, shipping, and commercial fishing (Halfacre-Hichcock et al, 2005). Future growth in the tri-county region is projected to occur primarily in new developments on the fringes of existing development and is expected to increase nonpoint sources of pollution in local waterways. Significant increases in nonpoint pollution are expected in several rivers and their tributaries, including the Stono, Ashley, Wando, and the lower reaches of the Cooper (BCD Plan, 2000). In addition to pollution concerns from development, salinity alterations and saltwater encroachment are also a serious threat. A local study on the effects of watershed development on tidal creeks in Charleston Harbor estuary found that the macrobenthic organism community structure was altered in creeks that drained urbanized watersheds and that the variation in salinity was greater in creeks adjacent to suburbanized, urbanized, and industrialized land as compared to forested upland creeks (Lerberg, 1997).

Regional Stormwater Regulations and Management

Along the southeastern coast of the U.S., most regions have adopted and implemented the use of Best Management Practices (BMP) in an effort to control both stormwater quantity and quality. In South Carolina, these stormwater regulations typically focus on controlling runoff through three means. The first pertains to the total volume of runoff, requiring that either the first half inch of runoff is retained on site, or one inch of runoff from the built upon area, whichever is greater. The second, regulates runoff speed by requiring pre-development discharge rates to be maintained and the third focuses on quality during construction, mandating the removal of 80 percent of suspended solids (SMSRA, 1991; SCDHEC, 2002; 2003; 2006).

Stormwater Detention Ponds

Due to state regulations and regional geography and hydrology, an extremely common approach in South Carolina and especially the BCD region for addressing BMP requirements is to implement a stormwater detention pond.

Initially designed to manage localized flooding, stormwater ponds have recently become required as a device for treating stormwater and protecting adjacent water quality (SCDHEC, 2004). Generally, there are two categories of stormwater ponds, detention and retention. Both are designed to have a permanent pool of water, but in detention ponds the water is gradually discharged into adjacent water bodies through overflow structures, whereas in retention ponds, the water is slowly released through infiltration and groundwater transport. In 1999, it was estimated that over 8,000 stormwater ponds existed within just the eight coastal counties of South Carolina (Siewicki et al, 2007). According to local engineers surveyed in a 2009 coastal South Carolina stormwater management workshop, the stormwater pond will continue to predominate as the preferred stormwater BMP in the region. This preference is directly related to the ease of designing, permitting, and constructing ponds and also because of the valuable fill material that is essential when developing topographically low-lying areas. In addition, stormwater ponds are easily marketed in the development community as both an aesthetic and recreational amenity (Hernandez & Vandiver, 2009).

Recent regional research contradicts existing national research which suggested that ponds were effective mechanisms for reducing peak stormwater flows and retaining pollutants. This new research suggests that the efficiency of stormwater ponds in the region may not be as great as reported in the nationwide study (Messersmith, 2007). Besides efficiency concerns, stormwater ponds present a host of other potential issues related to water quality. Due to the nature of ponds serving as a receptacle for stormwater, they often receive high loadings of nutrients, pesticides, chemicals, and fecal coliform (Drescher et al, 2007). The impacted surface waters and sediments can create a pond environment that can be hazardous to the health of both fish and humans (Hernandez & Vandiver, 2009). In addition, the required maintenance on stormwater ponds is often overlooked, allowing sedimentation to occur. Over time, a build-up of sediment effectively reduces the storage capacity of the pond, causing polluted water to discharge into adjacent water bodies (Messersmith, 2007). Despite the ubiquity of the stormwater pond in the BCD region, it is clear that there are many shortcomings to this preferred method of stormwater management.

Although the region presents significant physiographic barriers to the use of non-conventional LID techniques, the ecological and economical contributions of the BCDs waterways are invaluable to the health and viability of the region. Regional water quality conditions indicate that the combination of growth patterns and current stormwater management techniques are not adequately protecting the health of local water bodies. With the present rates of strong regional population growth and future projections high, it is important for the BCD region to assess the adequacy of its current stormwater management regulations and practices in providing for this growth while also achieving and maintaining watershed quality and health goals.

CHAPTER EIGHT

SURVEY

In order to complement the literature-based assessment of LID in the BCD region of South Carolina, a survey was designed to be administered to local landscape architects in the private sector. (As noted in the Methodology chapter, the survey was ultimately administered to engineers and planners, as well as public sector landscape architects.) Landscape architects (and other land development professionals) are an integral part of the land development process and therefore have the potential to influence stormwater management trends. This survey was devised to gain insight into those factors which are affecting the stormwater management decisions being made by these land development professionals, including LID awareness, usage, perceived benefits, barriers and opportunities. Ultimately, the goal of the survey was to provide regionally appropriate strategies that could help facilitate an increased usage of LID in the BCD area.

Gauging overall awareness of the concept of LID by local professionals was accomplished in section two of the survey. Information identifying how, where, and why specific LID techniques are currently being used in the BCD region and to what success was captured in section three of the survey. An assessment of the real and perceived benefits was handled by section four and barriers to LID usage were addressed in section five. Section six of the survey focused on uncovering the resources and methods for overcoming the barriers while the last section, seven, served to identify any opportunities that may exist for advancing more sustainable approaches to stormwater management, such as LID. A detailed discussion of the objectives of each of the seven survey sections follows.

Part One: Background Information

Understanding individual's backgrounds and company dynamics is essential to making gross assumptions based on similar capacities. Part one of the survey served to collect general background information about the participant and firm, including participant occupation and disciplines in organization.

Part Two: Awareness

The overarching terms 'Low Impact Development' and 'Green Infrastructure' have been used in recent years by many municipalities across the nation attempting to incorporate more sustainable stormwater management approaches into their jurisdictions. In looking at both new areas being developed, as well as infill areas being redeveloped, municipalities are advocating numerous types of in-situ water infiltration and management techniques, as well as encouraging the use of programs such as LEED to improve development and redevelopment in their jurisdictions on a site by site basis. The survey participants' professions make them instrumental in influencing land development; understanding what sort of knowledge they possess regarding 'green' alternatives is essential to identifying why certain decisions are being made and thus was the impetus behind section two of the survey. In order to achieve a more in-depth understanding of specific LID-related knowledge, the second section, which was focused on green infrastructure awareness, inquired about participant's knowledge of local stormwater regulations, national 'green' certification programs, and eight specific LID treatments. Questions like these help to establish general baseline awareness levels for each individual, serving as possible indicators for LID patterns of usage and success.

The eight specific LID treatments about which participants were asked were: pervious pavements, bioretention, open space/buffer preservation, inlet/filter systems, extended detention basins (wet/dry), below-ground detention/infiltration, vegetated swales, and engineered wetlands. Each is described in greater detail in chapter five.

Part Three: Use

Today, terms such as sustainability, eco-friendly, and 'green,' have become quite ubiquitous in our culture. Although many towns and business want to portray an image of sustainability, the practical application of the concept can be more elusive. In section three, a variety of general and specific questions were posed in order to quantify use of LID techniques, assess level of satisfaction with LID projects, and to ascertain why and how usage was being influenced. The questions in this section help to measure the overall usage and success of local LID efforts and highlight regionally relevant factors impacting use.

Preferences for and successes of specific Low Impact Development techniques can hint at potential barriers and opportunities within the BCD region. Each LID treatment ultimately achieves a reduction in runoff, what differs is the factors surrounding how it functionally achieves this reduction. Some of these factors include: overall maintenance requirements, ability to reduce hard infrastructure, cost efficiency, ability to meet LEED requirements, eco-friendly image/appeal, availability of tax credits or incentives, previous use or knowledge of a specific technique, and ability to impact watershed health. Appeal of certain LID techniques is likely related to a combination of these factors; therefore, assessing which factors are driving the usage of certain LID techniques and which are being successfully implemented helps highlight important regional aspects such as what is important or what is valued in the development process or where changes may need to be made.

Part Four: Benefits

Stormwater management has long been dominated by the discipline of engineering, a field that relies heavily on water calculations and modeling, as mismanagement of stormwater can and has lead to loss of property and life. As LID is a relative new-comer to the realm of stormwater management, when suggesting a more sustainable alternative it is critical to not only understand the functional benefits of managing stormwater differently than what has been done historically, but to also be able to communicate those benefits to clients, municipalities, etc. Utilizing LID is a conscious design decision to go 'against tradition' and recognize there is not only an opportunity to be more ecologically sensitive, but to also influence a movement towards 'greener' development practices.

Section four of the survey is dedicated to identifying, from among the various benefits associated with LID, which ones provide the greatest value and motivation. Understanding what is valued, by whom, and why can aid in targeting both small and larger scale LID efforts by capitalizing on what is most relevant to particular groups.

Part Five: Barriers

Barriers to LID surface during all stages of the development process and each presents its own set of obstacles; some are real, some are perceived, some are internal, and some are external. Certain barriers are easier to overcome than others. Sections five solicits participants for their experiences with a variety of known barriers to LID and attempts to assess which are the most prohibitive.

Part Six: Negotiating Barriers

Identifying barriers is just one step in the process to further the adoption of sustainable alternatives to stormwater management. Understanding what tools and resources local professionals need and rely upon to assist in overcoming barriers, as well as the "paths of least resistance," are crucial components to facilitating the widespread use of these techniques. Section six questions aim to uncover how the professionals have been able to improvise and adapt to overcome certain barriers, while prodding for those barriers that have yet to be surmounted, indicating areas where greater effort and creativity may be required.

Part Seven: Opportunities

In the last section, participants are pressed to rely on their professional expertise in order to identify opportunities that may exist for Low Impact Development in the BCD region. Recognizing how to judiciously capitalize on local resources that might be favorable to the support, awareness, cost, and application of sustainable alternatives to stormwater management is a crucial step in the proliferation of LID in the BCD region.

A complete copy of the survey can be found in Appendix A. It is important to note that during the interview process, it was discovered that part 'b' of question number 31 was not a valid question and the decision was made to exclude it from all survey interviews.

CHAPTER NINE

SURVEY RESULTS

The purpose of this chapter is to provide detailed results of the "Alternative Stormwater Management Techniques and Barriers" survey that was administered to landscape architects, planners, and engineers. Results from this survey's questions related to LID awareness and usage, as well as benefits, barriers and opportunities, help provide the final piece in gaining a comprehensive appreciation for the state of LID in the BCD region. Collectively, these results are beneficial in defining strategies and recommendations to facilitate an increased usage of LID in the BCD region. The results presented in this chapter will be organized as the survey was designed and administered: Background Information, Awareness, Use, Benefits, Barriers, Negotiating Barriers, and Opportunities. Following the detailed results, this chapter will conclude with a summary of the key findings as related to the thesis research questions.

Part One: Background Information

The survey was administered to a total of twenty-one participants involved in land development, including fourteen landscape architects, four planners, and three civil engineers. Fourteen of these professionals are employed in the private sector and seven in the public sector; Table 9.1 provides a breakdown of the number and type of professionals representing each sector. Among the fourteen landscape architects, eight are employed by independent, landscape architecture-only firms, four are associated with multi-disciplinary firms and two are in the public sector. Both of the civil engineers from the private sector work for multi-disciplinary firms. An interesting side note is that two of the four planners surveyed have backgrounds in landscape architecture.

	Landscape architects	Planners	Civil Engineers
Private	12	--	2
Public	2	4	1

Table 9.1: A breakdown of survey participants

Part Two: Awareness

The survey participants' have significant potential to influence land development; understanding what sort of stormwater knowledge they possess, particularly related to 'green' alternatives, is essential to identifying why certain stormwater management decisions are being made and can contribute to identifying strategies for expanding the use of LID.

1. Please indicate how knowledgeable you are with the LEED certification process (i.e. if you have passed the LEED exam you are considered very knowledgeable).

As was expected, most respondents were familiar with the United States Green Building Council's (USGBC) LEED program. The LEED program has garnered significant attention and is a recognized symbol of the 'green' movement by both land development professionals and the general public. On a scale ranging from one to six, with one representing 'no knowledge' and six representing 'very knowledgeable', the average level of LEED knowledge was 3.9. Further analysis reveals that the landscape architects in private practice have the most LEED knowledge with an average of 4.8 and the group with the lowest average score was the entire public sector respondents, which rated themselves at an average of 3.5. These numbers are logical as the LEED accreditation and continuing education processes for individuals has been noted by many respondents as being expensive and these costs may not be justifiable in the public sector. In addition, LEED and other green infrastructure initiatives are often considered as a valuable marketing tool to those in the private industry. However, with the strong desire of many municipalities to be perceived as more ‘eco-friendly’ and to gain the recognition that LEED projects often garner, it would be valuable for public sector professionals to be knowledgeable on LEED projects that they might oversee.

2. Please indicate how knowledgeable you are with ASLA’s Sustainable Sites Initiative (SSI) (i.e. if you can identify a specific case study, you are considered very knowledgeable).

When assessing knowledge related to the American Society of Landscape Architect's Sustainable Sites Initiative (SSI), respondents were less aware of this program than the USGBC LEED program. Although the content of this program is more directed toward sustainable land design practices whereas LEED has a greater focus on the building, SSI is a relatively new initiative that is still in its formative stage so it was expected that there might be a decline in the statistics representing knowledge. Collectively, on a scale ranging from one to six, with one representing 'no knowledge' and six representing 'very knowledgeable', all respondents averaged to just above a three for SSI knowledge. Again, the group comprised of just landscape architects in private practice was the most knowledgeable, at just over a four, while the public sector group again received the lowest average score. The disparity in knowledge was much more drastic, with the public sector group averaging only a 1.7. It is interesting to note that the landscape architects in private practice scored themselves as more knowledgeable in the LEED program than in this initiative, which is co-sponsored by the American Society of Landscape Architects, their professional society.

3. Please indicate how knowledgeable you are with specific county regulations regarding stormwater management.

Comparing knowledge of stormwater regulations for each of the three counties using a scale from one (no knowledge) to six (very knowledgeable), participants were the most familiar with those regulations in Charleston County and had the least knowledge of regulations in Berkeley County. Overall, the average scores for Charleston, Dorchester, and Berkeley counties were, respectively: 3.4, 2.7, and 2.5. These scores are on the lower side of the scale, which means as a group, there are large gaps in knowledge regarding local stormwater regulations and there is also minimal difference in the overall knowledge of regulations in Dorchester and Berkeley counties. These figures may or may not be the result of the amount of work individuals have performed in a specific BCD county, which could also be an indirect reflection of the overall growth in that particular county. Out of all the survey respondents, the most knowledgeable were the engineers, which averaged out to close to six for all three counties. In comparison, landscape architect's knowledge of stormwater regulations for the three counties was in the 2.8 to 3.8 range, with Charleston County's regulations being the most well known. During the survey, it was regularly noted by landscape architects that the civil engineers know more about the stormwater regulations because they deal with the specific details and quantification aspects of stormwater management, whereas the landscape architects involvement is in more of a general design capacity. Some even commented that they are often brought into the project later in the development process, when decisions related to stormwater management have already been established by civil engineers. The lesser degree of knowledge possessed by landscape architects may be a by-product of the reduced role that they have been indirectly assigned in the stormwater management process. However, it may also be due to a lack of professional requirements related to local stormwater regulations.

4. Please indicate how knowledgeable you are about each LID technique (i.e. if you have practical experience in the design and or implementation of the techniques, you are considered very knowledgeable).

Participants were asked to rate on a scale of one (no knowledge) to six (very knowledgeable)their knowledge of seven standard LID approaches such as pervious pavements, bioretention, and inlet/filter systems. Table 9.2 provides a breakdown of the average knowledge possessed by all respondents for each LID technique , as well as which industry sector they represented. The two techniques that consistently rated highest for knowledge across the disciplines and sectors were pervious pavements and open space/buffer preservation while engineered wetlands was rated the lowest. Most of the BCD region seemed to

	Pervious Pavement	Bio-retention	Open Space/Buffer Preservation	Inlet/ filter systems	Extended detention basins (wet/dry)	Below-ground detention/ infiltration	Veg. swales	Engineered wetlands
All	4.8	4.3	4.8	3.1	4.0	3.4	4.5	2.8
Public sect.	4.8	4.1	5.1	3.2	3.9	3.1	4.4	2.6
Private sect.	5.8	5.3	5.6	3.7	4.9	4.3	5.5	3.6
Multi-discipl.	5.8	5.7	5.8	4.1	5.1	4.8	5.6	3.5
Landscape arch.	5.5	4.9	5.4	3.3	4.4	3.7	5.2	3.4
Civil engineers	5.3	5.0	5.7	5.3	6.0	6.0	5.3	3.0
Landscape arch, public sector	4.9	4.4	5.0	3.1	3.7	3.0	4.6	2.6
Landscape arc.h, private sector	5.7	5.1	5.6	3.3	4.8	4.0	5.4	3.7

Table 9.2: Participant’s knowledge of eight common LID treatments

encourage the incorporation of buffers and open space into projects and in fact it was noted by many participants that it is often a requirement in certain jurisdictions. Generally speaking, less knowledge is usually a direct result of lesser usage of a technique. With the case of engineered wetlands, one respondent noted that clients typically have little desire for implementing something on their land over which they have no control or cannot change at a later date. With wetlands, once created on any property, the state takes over jurisdiction.

Part Three: Use

The following questions are meant to provide a comprehensive assessment of where, why, and how LID is being applied in the Charleston metro region (BCD). Measuring overall usage and successes of local LID efforts can highlight regionally relevant factors impacting use, and guide plans for improving the opportunities for LID use in the BCD region.

5. Have you ever implemented LID in a project in the Charleston metro region?

Of the 21 survey respondents, only one participant had not implemented LID in a project within the BCD region; however, they had been involved with various other local LID projects that had either been shelved or had the LID component rejected prior to implementation. This individual is employed by a small landscape architecture firm that focuses primarily on high end residential design. This participant noted that, especially within the historic downtown section of Charleston, the use of LID is often infeasible due to LIDs limitations of plant palette and the overall urbanization of the area. Further, certain LID techniques often have the perception of possessing a natural or 'wild' feel that can clash with the more manicured appearance of homes and existing landscapes in the historic downtown. Additionally, most of the downtown land is fully developed with little room for what can often be considered space-consumptive techniques that might also be disruptive to pedestrian circulation.

6. Please rate how satisfied you are with the total number of your projects that have included LID techniques.

When asked about satisfaction level regarding the total number of projects that have included LID techniques, on a scale ranging from one (very dissatisfied) to six (very satisfied), the average for all respondents was a three, demonstrating a general desire for more green infrastructure in the BCD region. The average remained a three when isolating respondents from the public sector and those from the private sector; however, when looking solely at landscape architects in private industry, the level of satisfaction increased to a four. The fact that this group rated higher than any other group for the total number of projects may be related to landscape architects position in the private industry. Working in the private sector alleviates the potential opposition from the general public and may also provide greater opportunity to assuage any concerns with direct client interaction and education, resulting in more opportunities to utilize LID. It also might be linked to the fundamental principles associated with the profession, which make landscape architects more focused on sustainable land development practices than the other professions.

7. Please rate how satisfied you are with the results of your projects that have included LID.

With an average just above four on a scale of one (very dissatisfied) to six (very satisfied), participants are generally content with results of projects that have included LID. While this question predominantly focuses on overall aesthetics and function of the LID treatment, the biggest reason for any dissatisfaction was related to maintenance. A lack of knowledge regarding proper maintenance leads to issues with functionality and aesthetics. It was also noted that since LID is relatively new, the track record of these techniques has not truly been proven, so there was some hesitation in providing an excellent review, but so far participants have noted that the LID projects are delivering.

8. Approximately how many of your projects in the Charleston metro region since January 2010 included LID elements/techniques?

8. a. Roughly, what percentage of your total Charleston region projects does this number represent?

Although it was noted that the economy has significantly impacted the amount of work these professionals are receiving, only three individuals saw the use of LID in twenty or more projects since 2010. The mean number of LID projects implemented in this timeframe is six to ten. Comparing respondents from the private sector with those in the public sector, the public sector seems to have involvement with more projects containing LID. In the private sector, almost 65 percent of respondents had zero to five projects that included LID since the start of 2010. On the public side, 100 percent of respondents had six or more projects which incorporated LID techniques since 2010.

	None	5 or less	6 to 10	11 to 20	20 plus
All	2	7	4	5	3
Public sector	--	--	2	3	2
Private sector	2	7	2	2	1

Table 9.3: Number of projects in BCD region since 2010 that have included LID

	None	Less than 10%	11 to 25%	26 to 50%	More than 50%
All	2	7	2	2	8
Public sector	--	3	--	--	4
Private sector	2	4	2	2	4

Table 9.4: Percentage of projects in BCD region since 2010 that have included LID

Out of all projects since 2010, the mean percentage of projects that have been implemented with LID is 11 to 25 percent. Just over half of the respondents noted that projects containing some form of LID comprised 25 percent or less of their total work. About one third of all respondents stated that more than 50 percent of their projects included LID, with equal coming from public and private sector participants. In the public sector, this translates into over half of the respondents noting that the total number of projects including LID represents at least 50 percent of the total work; this percentage drops to 29 percent in the private sector. These relatively low figures for LID in the BCD region many not only be a reflection of the poor economy, but may also correlate to a lack of awareness of certain LID techniques by professionals. It could also be an indication that the public education component advocating these more sustainable ideas is lacking and therefore local project owners and members of the general public are not easily persuaded to stray from conventional approaches.

9. What practices (three most common) do you most commonly use to manage stormwater sustainably?

9. a. Please provide examples of the LID techniques that were used to achieve these goals.

Respondents' top three preferences for sustainable approaches to stormwater management were quite varied. At just over twenty-five percent, reducing impervious cover was the most common method for managing stormwater sustainably in both private and public sectors, followed by infiltrating stormwater through pervious pavements, infiltration basins and trenches which amounted to seventeen to twenty percent in private and public sectors, respectively. It is not surprising to see these rather practical approaches to sustainable stormwater management at the top of the list.

	All	Private sector	Public sector
Reduce impervious cover	16	15	6
Disconnect impervious surfaces	1	1	0
Provide depression storage in landscape	7	6	3
Convey stormwater in swales to promote infiltration	7	5	4
Use biofiltration to provide vegetated and soil filtering	4	4	0
Evapotranspire	4	4	1
Infiltrate stormwater	11	10	4
Maintain natural drainage courses	7	7	2
Minimize use of clearing and grading	6	5	1

Table 9.5: Most common practices in the BCD region for managing stormwater sustainably

When comparing the approaches preferred by those in the private industry with those in the public sector, the techniques were mostly in-line with the exception of two categories: "conveying stormwater in swales to promote infiltration" and "using biofiltration to promote vegetated and soil filtering". Among the professionals in the public realm, there was a ten percent increase from just under nine percent to nineteen percent in the preference for use of swales and the reported preference for biofiltration dropped from seven percent to zero.

When asked to cite examples of LID techniques that were used to achieve the sustainable stormwater practices, fifty percent of those whom answered this part of the question cited the use of pervious pavement to reduce impervious cover. Based on actual examples of projects provided, it appears that most of the LID projects are occurring in Charleston County. This could be related to the sheer volume of projects, based on the overall population and rate of growth occurring in Charleston County or it could be related to the fact that participants were more familiar with its stormwater regulations.

10. Please indicate what percent of your projects that incorporate LID are of each type.

A majority of respondents prefaced their response to this question by noting that because of the current economic state, the percentages they were providing today were almost completely opposite of what they were just five years ago. Generally speaking, when the economy is strong, private sector work is plentiful and when it is depressed, the bulk of work shifts to the public sector. One of the more common commentary received with regards to this question was that with the poor economic conditions over the past several years, the numbers have shifted with a much greater proportion of projects falling into the public sector category. Looking at an overall breakdown of industry segments, commercial projects are currently outpacing both residential and industrial projects when it comes to incorporation of LID techniques in projects. Based on overall respondent's ratings, more than

	All	Public sector	Private Sector
Residential	37.8%	28.0%	42.1%
Commercial	53.4%	61.0%	49.9%
Industrial	8.9%	11.0%	8.0%
New Development	75.9%	95.0%	71.4%
Retrofit	24.1%	5.0%	28.6%
Private development	50.3%	68.8%	42.9%
Public development	49.3%	31.3%	57.1%

Table 9.6: Areas of development in the BCD region where LID is occurring

half of projects in the BCD region which incorporate LID are in the commercial sector, while industrial projects represent just fewer than ten percent. Isolating responses from those professionals working in the public sector, the percent of commercial projects which include LID rises to just over 60 percent. These figures may be slightly skewed because several participants mentioned that due to the company's focus or their specific responsibility within the company, they only deal with projects within one or two of the three types of industries in the question. Future ability to use for 'green' marketing may contribute to the predominance of commercial sector projects. Overall responses also indicate that a vast majority, over 75 percent of LID projects are new development rather than retrofit projects. In the public sector industry, the proportion of LID projects in new development surges to 95 percent. This is not surprising as virgin land often has less limitations and complications than land that is being redeveloped.

Existing infrastructure, possible soil contamination and the unknown all make retrofitting land less desirable. As one participant stated the older sites, or the sites that get developed first, are those in the best location, with the most favorable soils so retrofit projects may be appealing for different reasons. Clearly, these sites are valuable from a real estate perspective, which would contribute to their re-development desirability. Comparing private sector projects with public sector projects, the overall group ranked them fairly even. This ratio shifts to slightly favor public sector projects, fifty-seven: forty-three when private industry responses are analyzed and it flip-flops back to private sector projects at a much more disproportionate ratio when separating out the responses from those in private industry; there is a roughly a seventy to thirty split between the two sectors, with an emphasis on private sector projects.

11. Please indicate how often you apply LEED stormwater criteria to your stormwater management solutions on non-LEED projects.

When it comes to incorporating LEED stormwater criteria on non-LEED projects, participants responses averaged out to a 3.7, almost right in the middle of the scale from one (never) to six (every project) and the private sector responded slightly higher with a 4. For one private sector participant whom rated this question on the higher end, commentary was that a lot of clients are interested in LEED values but are not willing to pay for the LEED name. As noted by many in both the private and public sectors, LEED can be both costly and time-consuming. Another private sector participant whose answer ranked on the lower end of the scale remarked that there is often little opportunity to incorporate LEED stormwater criteria because all the stormwater work is typically done by civil engineers before the landscape architects get involved in the project. A respondent from the private sector whose rating of this question was a six stated that it makes sense for public sector projects to get LEED certified because there are tax credits available for these types of projects, but in the private sector it is often not worth getting the certification just to get a plaque to hang on the wall. Interestingly, when isolating the responses from the public sector professionals, the average response was rather low, just a 2.8. This may highlight an 'all or nothing' approach by the public sector where LEED projects include sustainable stormwater approaches but for projects that are not LEED, there is less focus on incorporating sustainable stormwater management techniques. It might also suggest that in public sector projects, it is easier to incorporate sustainable stormwater techniques when there are clear and quantifiable standards directing the project.

12. Please indicate how often you apply your Sustainable Sites Initiative (SSI) knowledge to stormwater management on non-SSI projects.

Respondents were slightly less likely to incorporate Sustainable Sites Initiative knowledge on non-SSI projects; the overall response averaged to just over three on a scale of one (never) to six (every project). Only one respondent, a landscape architect, rated use of SSI knowledge on non-SSI projects to be a six; whereas five respondents, all landscape architects, rated their use of LEED stormwater management criteria on non-LEED projects as a six. This directly relates to the lack of knowledge and even awareness of the Sustainable Sites Initiative.

13. Please indicate how often your use of alternative stormwater management techniques is hindered by specific <u>county</u> regulations.

Responses to this inquiry came back rather mixed. On a scale of one (never) to six (every project), the responses averaged out on the lower end, with a 3.2 for both Berkeley and Dorchester Counties and a 2.9 for Charleston County. One individual felt that although the counties may not necessarily prevent the use of LID, the techniques can rarely be used in order to receive credit for meeting regulations, which could be considered a hindrance. Several respondents identified potential county concerns with maintenance and ownership as the biggest culprit for impeding the use of LID, not the actual regulations.

14. Please indicate how often your use of alternative stormwater management techniques is hindered by specific <u>municipality</u> regulations regarding stormwater management.

At 2.7 on a scale of one (never) to six (every project), the group rated local municipalities' regulations as being slightly less of a hindrance to LID than local county regulations. Participants that rated the municipalities as 'never' hindering alternative stormwater techniques implied that municipalities have really opened up recently and become more supportive of creative approaches to stormwater management, which may be partially due to efforts towards staying in compliance with the National Pollutant Discharge Elimination System permit program. Some felt that the resistance was not so much at the municipal level, but more with certain project team members--specifically developers and engineers--who have a strong voice in the overall direction of the project. Breaking down the responses into groups, professionals representing businesses in the private sector rated municipality regulations at a three, while those in the public sector gave it a two. When looking at landscape architecture-only firms, the response from these individuals was a 3.4 which is higher than those landscape architects employed by multi-disciplinary firms, which rated the municipality regulations at a two.

15. Please indicate how often your use of alternative stormwater management techniques in projects is hindered by landscape design principles such as creating "place."

15. a. In your opinion, do you believe LID techniques generally detract from the qualities of a "place," such as aesthetics, livability, and connectivity?

Overall, most participants did not believe that LID and landscape architecture principles such as creating "place" were incompatible; this was reflected in an overall average of 2.1 on a scale of one (never) to six (every project). For those that felt there was some degree of restriction, all comments related to the challenges of incorporating LID into an urban environment and the limitations in plant palette and zoning regulations, particularly in a historic downtown such as the peninsula of Charleston. This comment highlights the idea that there may be differences in what works in an urban environment versus a more suburban setting. Not a single respondent considered LID techniques to detract from the qualities of a "place" such as aesthetics, livability, and connectivity. Many did note however, that it is a matter of preference and outside of the professional world, there is often an important educational component lacking that is essential to influencing perception of LID qualities.

16. Based on your experience, which (one) group do you feel generally exerts the most influence over stormwater management today?

Originally intended to be a single response question about the group which exerts the most influence over stormwater management, it was evident from the number of multiple answer responses, that there was a greater degree of complexity involved with stormwater management authority. Twenty-one respondents gave a total of thirty-two responses. Of these responses, three groups did not receive any votes--landscape architects, the clients, and the general public. Leading the groups, with almost one third of the total votes, were the engineers, followed closely by the state government. Although civil engineers received the most individual votes, overall, respondents rated the collective levels of government (63%) as more influential than the land development professionals (38%). The difference in votes separating state

Landscape architects	--
Civil engineers	10
Developers	2
Clients	--
Local government	6
State government	9
Federal government	5
General public	--

Table 9.7: Groups considered most influential to stormwater management

government from local government and federal government was rather limited. The fact that engineers and state government received such comparable scores may be partially due to the fact that the profession of engineering is tightly regulated by the state. Clustering of votes for each level of government potentially alludes to a lack of cohesiveness among governmental agencies and their regulations. Generally speaking, the respondents recognized the federal government as being the provider of general criteria, which the state than adapts into specific mandates and passes along to the local governments.

17. When LID techniques have been used in projects for stormwater management, which of the following is the most common primary goal?

Among all professionals interviewed, managing stormwater on-site was the primary goal when LID techniques were used in projects for stormwater management, receiving almost sixty percent of votes. Essentially, these results indicate that the underlying motivation for utilizing LID is tied to its ability to meet regulations and not necessarily for its capacity to manage stormwater sustainably. Most felt there were multiple reasons for using LID and therefore some participants had difficulty recognizing just one main goal. One individual commented that the primary focus should not simply be on managing stormwater on site, but unfortunately it is. A distant second-place with just over a quarter of the votes was the goal of protecting or enhancing water quality through the use of LID.

	All	Public sector	Private sector	Landscape architects	Civil engineers
Manage stormwater on site	13	5	8	8	1
Protect/restore riparian zones, wetlands, buffers, etc.	1	--	1	1	--
Protect/enhance water quality	6	3	3	2	2
Reduce burden on community stormwater systems	2	--	2	2	--
Store and harvest to reduce potable water needs	--	--	--	--	--
Provide additional site amenity	--	--	--	--	--

Table 9.8: Primary goal when implementing LID techniques

18. Have you ever used LID techniques to achieve credit toward any certification initiative such as LEED or SSI?

18. a. Which techniques have you most commonly used in LEED projects?

A majority of respondents, almost sixty-two percent, have used LID techniques to achieve credit toward a certification initiative such as LEED or SSI in the BCD region. One participant indicated that the points available through LEED for sustainable stormwater management are a bit limited. According to the participant, there are two means through which points can be achieved for managing stormwater, water quality and water quantity. Quality points are easier to achieve because if a project meets the state's requirements, it also meets the LEED requirements; however, the quantity points are harder achieve. States generally regulate the rate of runoff and do not typically address the volume of runoff. Meeting rate requirements is fairly common and has been around for some time so there are standard approaches for it, specifically detention ponds. Meeting volume requirements, however, requires additional mediums for using or eliminating stormwater through the use of infiltration, evapotranspiration, or harvest and reuse. This is where LID approaches become valuable. Another respondent who has not used LID to achieve credit for LEED or SSI remarked that many clients start out with an interest in LEED but then quickly drop the idea once they discover how costly it can be.

It appears that a variety of LID techniques are used to achieve credit toward LEED projects. Each category of LID techniques was utilized to achieve credit, except for engineered wetlands.   Receiving just under a quarter of all responses, the most common techniques was pervious pavement, once again. A close second was the use of open space or buffers and vegetated swales, each of which received almost an eighteen percent share of the responses.

Pervious pavements	13
Bioretention	8
Open space/buffer preservation	10
Inlet/filter systems	5
Extended detention basins	5
Below-ground detention/infiltration	6
Vegetated swales	10
Engineered wetlands	--

Table 9.9: LID techniques most commonly used in LEED projects

19. When using LID in a project, how often do you incorporate each technique?

In comparing frequency of use for certain techniques in any (LEED or non-LEED) project on a scale of one (never) to six (frequently), pervious pavements were again the most commonly used technique with a score of 4.9, followed closely by

Pervious pavements	4.9
Bioretention	3.4
Open space/buffer preservation	4.6
Inlet/filter systems	2.8
Extended detention basins	4.4
Below-ground detention/infiltration	2.5
Vegetated swales	3.9
Engineered wetlands	1.5

Table 9.10: Most commonly used LID treatments

‘open space or buffer preservation' and extended detention basins. Based on a score of 1.5, engineered wetlands are almost never utilized in the region for stormwater management. There is almost a direct correlation between two of the commonly used techniques and the techniques which are most commonly utilized in LEED projects; pervious pavements and open space/buffer preservation topped both charts. Vegetated swales, which shared a second place position with 'open space or buffer preservation' when ranking the most common techniques used in LEED projects, dropped to a fourth

	All projects (frequency)	LEED projects (total number)
Pervious pavements	4.9	13
Bioretention	3.4	8
Open space/buffer preservation	4.6	10
Inlet/filter systems	2.8	5
Extended detention basins	4.4	5
Below-ground detention/infiltration	2.5	6
Vegetated swales	3.9	10
Engineered wetlands	1.5	--

Table 9.11: A comparison of LID frequency in all projects with usage in LEED projects

place ranking with a score of 3.9 for general frequency of use in any LID project. Interestingly, extended detention basins, which were ranked third in frequency of use for general LID projects, fell almost completely to the bottom of the chart in LEED project usage. This reinforces the idea that there are more environmentally-friendly alternatives to the widely-used detention pond. When comparing the results for how often specific LID treatments are used within projects, with participants overall knowledge of each treatment (question number four), there is a strong correlation between increased knowledge and increased use and decreased knowledge and decrease use.

20. Based on your experience, how <u>easy to implement</u> is each technique?

Relative ease of implementation for LID techniques is based on collective experience with the design, approval, and installation process. Assessing overall

Pervious pavements	1.8
Bioretention	3.1
Open space/buffer preservation	1.6
Inlet/filter systems	2.5
Extended detention basins	2.2
Below-ground detention/infiltration	3.5
Vegetated swales	2.0
Engineered wetlands	3.7

Table 9.12: Overall ease of implementation of specific LID treatments

ease of implementation was done using a scale of one (extremely easy) to six (extremely cumbersome); not surprisingly, respondents ranked 'open space or buffer preservation' as the easiest. With regards to those techniques that require more engineering and design effort than preserving open space, pervious pavements was considered rather easy to implement. Engineered wetlands, which previous questions showed to be rarely used, was ranked as the most difficult; however, with the minimal amount of usage in local projects, it is surprising that it did not receive a higher average on the difficulty scale.

	Ease of use	All projects (rate)	LEED Projects (total number)
Pervious pavements	1.8	4.9	13
Bioretention	3.1	3.4	8
Open space/buffer preservation	1.6	4.6	10
Inlet/filter systems	2.5	2.8	5
Extended detention basins	2.2	4.4	5
Below-ground detention/infiltration	3.5	2.5	6
Vegetated swales	2.0	3.9	10
Engineered wetlands	3.7	1.5	--

Table 9.13: A comparison of the ease of implementation with the frequency of use in all projects and in LEED projects

Comparing the relative ease of implementation with the frequency of use and usage in LEED projects, there is almost a direct correlation between the three LID techniques rated as easiest to implement (open space/buffer preservation, pervious pavements, and vegetated swales) and the frequency of use in all projects and in LEED projects.

21 through 27: Generally speaking, when *[21. pervious pavements; 22. bioretention; 23. inlet/filter systems; 24. extended detention basins (wet or dry); 25. below ground detention/infiltration; 26. vegetated swales; 27. engineered wetlands]* were implemented, rate how strongly each factor influenced the decision to use it.

Any time a conscious decision is made to utilize LID techniques in addition to or instead of conventional stormwater management techniques, there are a variety of factors that would likely influence the decision to use a particular LID treatment. For the purpose of this study, there were eight factors identified as having the potential to impact the usage of a LID treatment including:

maintenance requirements, ability to reduce hard infrastructure, cost efficiency, ability to meet LEED requirements, eco-friendly image/appeal, availability of tax credits/incentives, prior use/knowledge of specific technique and impact on water quality/watershed health. A scale ranging from one (not at all important) to six (very important) was used to quantify how much each factor influenced the use of a particular LID treatment.

Most Influential Factors

By and large, responses demonstrate that for the seven different LID treatments, maintenance requirements are an important component of the decision-making process. Of the eight potential factors influencing use, pervious pavements,

	Maint. requirements	Ability to reduce hard infrast.	Cost efficient	Ability to meet LEED requirements	Eco-friendly image/ appeal	Tax credits, incentives available	Prior use/ knowledge of specific technique	Impact on water quality/ watershed health
Pervious pavement	5.1	5.0	4.8	3.6	4.2	2.0	4.5	4.9
Bioretention	5.4	4.5	4.5	3.8	4.1	1.9	4.3	5.2
Inlet/filter systems	5.3	4.2	3.6	2.9	3.6	1.8	4.1	4.9
Extended detention basins	4.8	3.8	4.2	3.0	3.5	1.7	4.8	5.2
Below-ground infiltration/ detention	5.4	3.8	4.8	3.6	2.8	2.2	4.5	4.4
Vegetated Swales	4.9	4.7	4.6	3.5	4.6	2.0	4.2	5.1
Engineered wetlands	4.9	4.0	3.7	2.7	4.4	3.4	4.5	5.1

Table 9.14: Factors influencing the decision to utilize a specific LID treatment

bioretention, inlet/filter systems, and below ground detention/retention all had 'maintenance requirements' ranked as the most important of the factors. In the remaining three LID treatments, 'maintenance requirements' was also ranked very high. Maintenance requirements and ownership was a big discussion point throughout the usage section of the survey. From the perspective of the clients, the additional costs associated with special maintenance requirements are a big concern. On the professional side, the focus was more on the importance of proper maintenance to ensure functionality and aesthetics. Without appropriate care, the treatment would languish, reflecting poorly on the designer. For those in the public sector, equally important as 'how to maintain,' is who will be maintaining it. Ensuring clearly defined maintenance responsibilities helps prevent unintentional neglect as the years pass or as property transfers to new ownership. Without clear designation of maintenance obligations, it is possible that over time, the LID treatments, as any improperly maintained system, would fail and ultimately burden the existing stormwater infrastructure. Averaging just slightly lower than maintenance requirements on the scale of importance was the potential to impact water quality or overall watershed health. It is interesting that overall maintenance concerns factor more strongly than the basic goal behind the use of LID, which is to replicate pre-development hydrology in an effort to ultimately impact the local watershed in a positive way.

Least Influential Factors

At the other end of the spectrum, the availability of tax credits and incentives consistently ranked as having the least influence with regards to usage for all LID treatments, except engineered wetlands. Generally speaking, none of the respondents were aware of any specific tax credits or incentives. One participant explained that there might be a few vague credits available but that the typical developer is not going to put forth the time and effort to hire an accountant in order to uncover and understand any credits. Tax incentives and financial credits, according to this participant, are typically more readily available to companies that a county or municipality may be 'courting' to invest in their economy through new buildings and jobs. Often, the officials in the region will do all of the groundwork to identify the credits and offer these incentives to help entice the company to the area.

Ranking just above tax credits and financial incentives was the 'ability to meet LEED requirements.' Most participants did not feel that LEED played a pivotal role in the promotion of alternative stormwater management techniques. In fact, LEED, according to some survey responses, seemed almost counterproductive to the overall sustainable stormwater management movement. Several respondents felt that there were a limited number of points available for water quantity and quality management in the LEED program and that the rating system often resulted in misdirected focus on the part of clients. Instead of trying to understand and implement what is best for the site, individuals get caught up in the numbers and concentrate on the easiest or cheapest method of accruing points in order to achieve the LEED certification. Additionally, LEED was considered by most of the respondents to be a rather expensive and time-consuming process. It was common, many participants noted, for clients initially interested in LEED certification to abandon the idea before the process was complete. Clients are rightfully budget minded, so if a LEED certification price tag is already impacting their bottom-line, the likelihood that they will incur additional expenses to incorporate green stormwater infrastructure is significantly reduced.

Most and Least Influenced LID Treatment by Factor

Maintenance Requirements

Examining each of the eight factors individually and assessing which specific LID treatment received the highest score in each category, illustrates which factor likely has the greatest influence on the usage of which specific LID treatment. The LID treatment that received the highest ranking for 'maintenance requirements' was bioretention. This ranking was also the highest overall average score when comparing all eight factors against all seven LID treatments. Bioretention, which is one of the more natural LID approaches, relies on soil and vegetation to remove pollutants from stormwater runoff and can also be used to achieve quantity control. Just as any landscaped area, bioretention requires seasonal maintenance to thrive; however, contrary to survey opinion, some sources claim the initial maintenance to establish the vegetation may be intense, but in the long term, less maintenance is required (Bioretention Fact Sheet, 2011). Many respondents seemed somewhat intimidated by the ability to accurately quantify such a naturalized system, especially with the variability from site to site in the form of existing soils, plant materials used, etc.

Conversely, the LID treatment that respondents ranked the lowest, as far as the influence of maintenance requirements on the decision to utilize, was extended detention basins. This rating implies that the general perception of detention basins is that the maintenance requirements for these treatments are better understood and/or less intense. Extended detention basins, or as they are frequently referred, stormwater detention ponds, are very common in the coastal region of South Carolina. An unfortunate consequence of the familiarity with these LID treatments is that they can easily be neglected and not regularly maintained. As a result, sedimentation can lead to a reduced storage capacity and thus an increase in discharge of polluted water to adjacent water bodies (Messersmith, 2007). In a separate survey recently performed, participants noted that it was difficult to assess the functional health of a pond and that often times these ponds are unfortunately only maintained for aesthetics (Vandiver and Hernandez, 2009).

Ability to Reduce Hard Infrastructure

For responses indicating the relative importance of the 'ability to reduce hard infrastructure', the highest overall score was associated with pervious pavements and the lowest was associated with both extended detention basins and below ground detention/infiltration basins. Basins typically allow for the collection and containment of large amounts of stormwater runoff, which can sometimes actually encourage or support additional hard infrastructure. This is particularly true with the below ground basin which, because of its subsurface location, does not consume any buildable land area, therefore allowing additional hard infrastructure to be built. In fact, it was noted by many respondents that this is often the only reason that developers will implement this form of LID.

Cost Efficiency

When comparing the treatments where cost efficiency was most and least important, pervious pavements was at the top of the rankings, indicating that pervious pavements are not viewed as a cost efficient alternative and inlet/filter systems was at the bottom. Although participants clearly believed the cost for many pervious pavements had declined recently, this was still a big concern with overall cost associated with its use. Not only is it generally more expensive to utilize certain types of pervious pavement than most traditional impervious surfaces, often the cost for long term maintenance combined with initial costs, causes pervious pavements to be considered not very cost efficient. In addition, if the pervious material is asphalt or concrete (which relies on pores in the material to penetrate water) and it is not properly maintained, the pores will eventually fill up and the pervious nature of the material will be lost, resulting in the need for replacement.

Ability to Meet LEED Requirements

In the ‘ability to meet LEED requirements’ category, bioretention averaged out to be the treatment most influenced by this green building initiative. Bioretention can be used for both water quality and quantity control, so it is valuable in terms of meeting LEED stormwater requirements and getting the coveted LEED points. According to survey respondents, LEED was least influential when considering the use of engineered wetlands.

Eco-Friendly Image/Appeal

Opposing ratings were received by the LID treatments, vegetated swales and below ground detention/infiltration basins, in the category assessing eco-friendly image or appeal. For obvious reasons, participants felt that if a treatment was situated below-ground, it was not visible to the general public and therefore visual image or appeal would have little to do with its use. On the other hand, vegetated swales are a very visible feature in the landscape and respondents felt that although every individual might not be fond of the natural appearance of vegetated swales, on the whole, it definitely was associated with an eco-friendly image.

Availability of Tax Credits/Incentives

Overall availability of tax credits or incentives was not generally perceived to be a significant factor for any of the LID treatments. The treatment that was ranked as having the least implications from incentives and credits was extended detention basins. These basins were considered to be so commonplace that there would be no reason to incentivize their use. Conversely, many respondents noted that some form of incentives exists for engineered wetlands in the form of wetland mitigation banks and density credits.

Prior Use/Knowledge of Specific Technique

As far as prior use or knowledge of the specific technique, respondents felt it was a very important factor influencing the use of extended detention basins. Regularly described as the ‘tried and true’ stormwater management approach, detention basins have been around for many years, have established credibility as a reliable control with regulatory agencies and are considered a very easy and comfortable choice for engineers. There is minimal effort, time, and cost required during design and review processes, contractors are very familiar with the construction of these features, and because of their extensive use, they present little concern as far as liability. Considered to be least influential, with regards to previous knowledge, was the use of inlet/filter systems. For this treatment, respondents often noted that manufacturers were very supportive and helpful, providing data, drawings, almost anything that would be needed for approval.

Impact on Water Quality/Watershed Health

Finally, assessing how each LID treatment ranked with regards to how influential its impact was on water quality or overall watershed health, the breakdown was as follows: extended detention basins received the highest average score, with bioretention scoring just a fraction lower; not far behind were engineered wetlands and vegetated swales; the order of the remaining three LID treatments was pervious pavements, followed by inlet/filter systems, and below ground detention/infiltration was last.

It is not completely surprising to find extended detention basins ranked so highly; their widespread use in the BCD region certainly exemplifies the value that is ascribed to them. There are a variety of benefits to stormwater ponds including the natural amenity they can provide in the form of aesthetics, open space, and recreation while also handling stormwater and providing fill material essential to sites in topographically low-lying regions. Recently, however, regional research suggests that ponds may not be as efficient in retaining pollutants and reducing stormwater peak flows as national studies have suggested (Messersmith, 2007). Additionally, there are other water quality concerns that surround the use of stormwater ponds. First is the fact that they are designed to retain stormwater, which means they inherently are subjected to high loads of nutrients, pesticides, chemicals, and fecal coliform (SCDHEC-OCRM, 2007). If this was the extent of use for ponds, this might be acceptable, but not only is there often exchange between ponds and adjacent tidal creeks, the ponds themselves typically attract both humans and wildlife and these conditions can be hazardous to the health of man and animal.

Part Four: Benefits

In this section, participants were inquired about perceptions of LID benefits to understand how this might influence their use of it through the following questions. An appreciation of what is valued and by who is advantageous to the crafting of successful efforts aimed at expanding successful LID implementation.

28. When trying to “sell” the concept of LID to clients, government, architects, engineers, etc. on projects—how do you sell the benefits of LID? What aspects do you cite?

Almost every participant, at one time or another, had attempted to justify the use of LID and many explained that the 'sales' technique varied depending on the audience. Undoubtedly, the most common approach cited by almost sixty percent of participants was to appeal in some manner to the project's bottom line by identifying cost savings, in either the short or long term. Most clients are business people and are ultimately concerned with profit. Providing a cost advantage was recognized as not only a beneficial tactic for selling the concept of LID, but also contributed significantly to overall client satisfaction, as the client feels his best interests are in mind. Not only was this the most common response, but it was clearly advocated as the most effective method for selling the idea of LID. The second most popular response was to promote the

Financial	57.1%
Environmental	38.1%
Marketing	28.6%
Aesthetic	23.8%
Meet requirements	9.5%
Faster approval/review	9.5%

Table 9.15: Benefits of LID as presented to potential clients

environmental benefits by highlighting the impacts of using LID. Although many people today have much more of an environmental conscience, this approach is not nearly as universally effective as emphasizing cost benefits. Respondents also were wary of the fine line that exists between the clients' perspective of being educated on a topic and being lectured. After environmental benefits, almost thirty percent of respondents considered there to be significant value in the marketing power of "green." Clients would be able to promote their project as sustainable and in turn, appeal to the strong environmental ethos prevalent among certain demographics today. Another common sales technique, as referenced by almost a quarter of respondents, was to promote the additional aesthetic value unique to many of the LID techniques. Only a small percent of respondents noted the possible advantage of an expedited review and approval process that often can be gained by the use of LID techniques.

29. From your experience, what are the client's interpretations of the benefits of LID?

29. a. Do you agree? Please explain

When asked to comment on what client's perceived the benefits of LID to be, by and large the answers all dealt directly or indirectly with money. For the most part, clients are concerned foremost with budget and overall return on investment. Not only do they appreciate and welcome techniques that can either save money or that will maximize developable land, they also appreciate the added value of "green" marketing. Generally, when asked if they agreed with the clients' perspective, most all respondents could identify with the business and financial concerns but many seemed to long for a deeper sense of stewardship among the development side of the business community.

30. When you choose to utilize LID, what are the top three primary motivations for doing so?

Responses shifted when participants were inquired about the primary motivations, professional and or personal, behind their usage of LID. As expected, a vast majority, over seventy percent, alluded to the sustainability of LID and the important environmental benefits it presents, including improved water quality, improved habitat and site ecology. One respondent said it just "makes perfect sense", relating it to the reason behind becoming a landscape architect in the first place. Another respondent summed up his personal

Environmental	71.4%
Meeting requirements	42.9%
Multi-functional	28.6%
Cost efficient	23.8%

Table 9.16: Participant's primary motivations for using LID

philosophy by quoting local, eminent landscape architect Robert Marvin with the statement "The land comes first." Emphasizing the practical side of LID techniques, over forty percent utilized LID as an alternative way of meeting project requirements, whether state or municipal water regulations or internal project requirements. The third most common motivation for employing the use of LID in projects was related to the multi-beneficial nature of many LID treatments. Not only do they manage stormwater on site, but they offer supplementary benefits of significant value such as aesthetics, sense of place, recreational opportunities, wildlife habitat, and an opportunity to utilize native plants. With money always seeming to be a focus, interestingly less than a quarter of respondents were motivated to use LID in part because it was considered to be relatively cost-efficient.

Part Five: Barriers

The next questions aim to understand what common barriers exist in the region and how influential they can be. Isolating these critical issues helps identify where efforts should be made to remove or overcome the barriers to LID, in theory, promoting increased usage.

31. Have you been involved in a project in the Charleston metro region where LID measures were designed/proposed/planned but ultimately not implemented?

31. a. If YES, rate each factor below as to how significant of a barrier it was to the implementation of the LID techniques.

Over seventy percent of all respondents had been involved in some manner with a project in the BCD region that had originally designed or proposed for the use of LID techniques, which were ultimately not implemented. Within the public-sector, responses drop to almost forty-three percent and in the private-sector, the percent soars to over eighty-five percent. In order to better understand why the LID treatment was not ultimately implemented, participants were asked to rate how significant of a barrier certain internal and external factors were to the project, including physical, political, financial, scientific, design, and maintenance-related barriers. Responses indicate that financial barriers were the most significant, with cost of implementation receiving an average score of 5.6 on a scale of one (not at all significant) to six (very significant). Together with the current poor economic state of the country, concerns over additional costs with newer LID technologies and expensive certification projects such as LEED, it is not surprising that these types of projects are abandoned.

Cost of implementation	5.6
Maintenance requirements	4.5
High groundwater table	4.1
Type of soil	3.9
Lack of performance data	3.8
Competing space requirements	3.4
Conflicts with municipal code requirements (i.e. curb and gutter, etc)	3.2
Lack of resources (i.e. design/ construction guidelines, etc)	2.9
Impact on the qualities of a “place” such as aesthetics, livability, connectivity	1.9

Table 9.17: Barriers to LID implementation in BCD projects

Maintenance concerns were the second most important barrier, followed by the physical limitation of a high groundwater table. Conversely, those factors considered to be least important were design-based and include impact on the qualities of a "place" (such as aesthetics, livability, and connectivity) and the availability of resources such as design or construction guidelines. In addition, several responses were received in the ‘other’ category, signifying that there were additional obstacles professionals found to be limiting when working with LID in projects. Most of these comments related broadly to the topic of education. One public sector participant noted that public perception can be quite influential to the fate of projects including LID. Certain demographic areas might be more accepting of LID; for example, rural areas might be more supportive due to the abundance of space and more naturalized areas that characterize rural regions and more educated communities may have a better appreciation for the philosophy behind LID. A private-sector participant also expressed the hurdle of dealing with clients that lack knowledge and therefore can not see the value of LID. Yet another educational hindrance was attributed by two respondents to resistance by and shortcomings in the knowledge of professionals involved in the collaborative design-build process.

32. Based on your experience please rate the <u>availability of resources</u> (performance data, design guidance, etc.) for each LID technique.

During the literature review, one identified barrier was a lack of resources such as performance data or design guidance. To better understand where the gaps were located, participants were asked to rate the availability of resources for each of the eight techniques previously discussed on a scale of one (poor) to six

Pervious pavement	4.9
Below-ground infiltration/ detention	4.5
Open space/buffer preservation	4.3
Extended detention basins	4.2
Vegetated Swales	4.0
Bioretention	3.9
Inlet/filter systems	3.8
Engineered wetlands	3.4

Table 9.18: Availability of resources ratings for LID treatments

(excellent). Average scores for all eight of the LID techniques indicate that, for the most part, there were no significant gaps in resources. However, it also suggests that there is definitely room for improvement with either the quality of resources or the availability for all eight techniques. A breakdown of the averages is located in Table 9.18. Although not precisely reflective of the ratings in the table, based on commentary received, it seems that the more manufactured LID systems generally have more data and design guidance available. From a manufacturer's perspective, these are important requirements when trying to promote and sell a product. Whereas the more natural systems such as bioretention, vegetated swales, and engineered wetlands are not products being sold by a manufacturer, there is often less data and design guidance readily available. It is interesting to note that the manufacturer-linked category of pervious pavements, which has been regularly rated as a top LID technique in previous questions, was also rated as having a great availability of resources.

Part Six: Negotiating Barriers

The following questions were asked of all participants in order to assess how obstacles are conquered and which need the greatest support in order to be overcome. Answers from this section provide good indicators of barriers where additional effort and creativity may be required and of tools and resources that have proven to been successful. This information is an essential component of a strategy aimed at overcoming barriers and facilitating widespread usage of LID.

33. Which site suitability barriers are the easiest to overcome in the Charleston region?

Through preliminary conversations with local professionals and individual research, several factors were identified as common physical barriers to the implementation of LID at both the regional level and beyond. Of particular local concern are the quick-draining, sandy soils, the high groundwater table, and the brief but intense precipitation events common, especially in the summer months. Therefore, using a scale of one (easy to overcome) to six (difficult to overcome), a question was posed regarding which site suitability factors were the easiest to overcome. All of the possible factors received rather high averages and are summarized in Table 9.19. Additional barriers were identified by several participants and they included contaminated soils, slope, wetlands, and existing vegetation. Due to the overall high level of difficulty participants ascribed to the

High groundwater table	5.3
Competition with right-of-way	4.9
Soils	4.7
Type of rainstorm event	4.4
Space constraints	4.3

Table 9.19: Relative ease of ability to overcome various site suitability factors

site suitability barriers, it seems important either for regional studies investigating solutions to these barriers be initiated, or for an in depth case study resource on these topics be provided.

34. How supportive of LID would you say the stormwater regulations are at each level of government?

Government policy has been widely recognized as potential sticking points in the approval and implementation of LID; this question attempted to pinpoint which level of government survey participants felt was the most supportive and which was the least. Overall results indicate almost a direct correlation in level of government and level of support. On a scale of one (prohibitive) to six (very supportive), the federal government was considered to be the most supportive with an average score of a 5.0. After federal, the respondents ranked municipal government at a 4.8, followed by county and finally state, which received an average score of 3.8. Even when separating the respondents

Municipal government	4.8
County government	4.3
State government	3.8
Federal government	5.0

Table 9.20: Relative supportiveness of the levels of government

into private and public sector, the ranking of each level of government remained exactly the same. Anecdotal commentary provided further insight into the ratings. It seems the federal government is considered supportive in the concept of Low Impact Development, as all stormwater mandates stem from the federal Clean Water Act and NPDES and also in the execution of federal projects such as those initiated by the Army Corps of Engineers or the Department of Defense; however, respondents generally felt the federal government fell short when it came to providing support in the form of resources and tools to promote real progress. For the most part, respondents felt that municipal governments were open and encouraging of new ideas related to LID and some are even requiring LEED certification of public projects. The City of Charleston has even created a new sustainability coordinator position. There were two specific areas of the government identified as being prohibitive; the first was municipal zoning codes to some degree, which establish local requirements related to development such as building setbacks and number of parking spaces and the second related to right of ways involved with any level of government. This comment alluded to the restrictiveness and lack of concessions when the Department of Transportation is involved.

35. Do you use any stormwater modeling tools?

35. a. If yes, which ones?

When participants were asked if they utilized stormwater modeling tools as part of the design process, only two of the landscape architects responded with a yes; one was from a multi-disciplinary firm and the other was from a small independent landscape architecture firm. Out of the three engineers surveyed, the two from the private sector utilized stormwater modeling tools, while the engineer in the public sector did not. Almost all the landscape architects that responded with a ‘no’ went on further to state that the civil engineers are the ones that use stormwater modeling tools. One particular landscape architect noted that modeling tools are extremely involved and rather complex, requiring significant education to be able to effectively utilize. Several different program names were mentioned: Interconnected Pond Routing (ICPR), SedCAD for sediment removal, Hydrograph, and SoftDesk, which is an add-on to AutoCAD. One participant commented that several tools were used because often the municipalities have specific requirements for the use of certain stormwater modeling tools, to keep the output consistent with what they use and understand. For efficiency and consistency purposes, identifying one main program as the standard for the tri-county area might help streamline the design and approval process.

36. What tools/resources do you utilize for design guidance?

Most designers, whether it is landscape architects or engineers, rely on a variety of resources for design inspiration and guidance. This is particularly important for emergent technologies or techniques, such as the relatively young concept of LID, with which the designer has little experience. To better understand what resources the local Charleston professionals were utilizing to aid with LID design guidance, participants were asked to note all mediums which they had found to be a helpful source. Eighty percent of those responding relied on the internet to supply them with valuable information. Fifty percent looked to specific organizations for their subject matter expertise. These organizations include

Websites	80%
Specific organizations	50%
Universities/affiliates	40%
Another state's manual	30%
Database	20%

Table 9.21: Tools/resources used for design guidance

the American Society of Landscape Architects (ASLA), the National Oceanic and Atmospheric Association (NOAA), South Carolina's Department of Health and Environmental Control (SCDHEC), DHEC's Office of Ocean and Coastal Resource Management (OCRM), the National Park Service (NPS), and both North Carolina and Florida's Department of Transportation. Only forty percent of respondents utilized a university or affiliate as a resource; those noted included: Clemson University's Cooperative Extension, the University of Georgia, Pennsylvania State University, Auburn University and North Carolina State University. Thirty percent of respondents relied on another state or locality's LID manual and only twenty percent utilized databases as references. Several respondents acknowledged additional resources upon which they have relied, including: books, product literature, seminars and continuing education opportunities, calling on someone more knowledgeable, a site visit, and zoning ordinances. It is obvious that the internet is a cache of information and whether it is the most relied upon resource because of its convenience or because it truly has the best information is difficult to discern; however, knowing preferences can help direct future educational and informational initiatives.

37. Which of the following have you willingly accepted in order to implement LID in a project?

In order to implement new approaches to stormwater management such as Low Impact Development treatments, sometimes concessions have to be made or extra effort put forth. Participants were questioned about what specific compromises they or their firm had been willing to accept in order to implement

	All	Public sector	Private sector	Multi-disciplinary	Landscape architects
Reduced profit	35.7%	100.0%	25.0%	16.7%	33.3%
Additional time/costs to educate firm members	78.6%	100.0%	75.0%	83.3%	66.7%
Additional time/costs to educate clients	100.0%	100.0%	100.0%	100.0%	100.0%
Lengthier review process	57.1%	50.0%	58.3%	50.0%	66.7%
Additional collaboration with other disciplines	57.1%	0.0%	66.7%	33.3%	100.0%

Table 9.22: Concessions made in order to implement LID in a project

LID in a project. One hundred percent of respondents had incurred additional time or financial costs in order to educate clients. About seventy-nine percent of respondents put forth extra effort to further educate members of their firm on related topics. Among respondents representing multi-disciplinary firms, the percent increased to eighty-three and in landscape architecture-only firms, the number dropped to two-thirds. Over half of all respondents endured a lengthier review process and also collaborated with other disciplines in order to implement LID. When further categorizing responses, one hundred percent of those from landscape architecture-only firms willingly collaborated with other disciplines to implement LID in a project, while only one-third of respondents from multi-disciplinary firms collaborated. In the private sector, the response rate was two-thirds and collaboration in the public sector was at zero percent. It is important to note that only two of the seven participants from the public sector actually answered this question. Only thirty-six percent of all respondents accepted a reduction in profit (or an increase in cost when dealing with public sector projects). For landscape architecture-only firms, this number stays roughly the same but it drops to seventeen percent when isolating responses from individuals in multi-disciplinary firms. Those respondents representing the private sector showed that only one quarter had willingly accepted a reduction in profit, whereas one hundred percent of public responses had accepted the equivalent increase in project costs in order to implement LID. This could imply that total costs, although important, may not be quite as influential to decisions in the public sector as it is to private industry firms that do not operate on tax money. Therefore, public sector projects become a great opportunity for implementing LID techniques, while also offering potential educational and research components.

38. Are there any changes that would need to occur to make you more likely to utilize LID in projects?

Soliciting participants for their perspective on what changes, if any, would be necessary to make them more likely to utilize LID in projects resulted in a variety of opinions as summarized in table 9.23. Only 2 participants responded that there were no changes that would make them more likely to utilize LID because

Finance	36.8%
Policy	26.3%
Education	26.3%
Research/data	10.5%
Maintenance	10.5%
Design	5.3%
General process	5.3%

Table 9.23: General areas where change was needed to support an increase in LID usage

they both felt they used it as much as possible. These were both private sector landscape architects, one from a multi-disciplinary firm and one from a landscape architecture-only firm. Out of those that offered suggestions, thirty-seven percent referenced the need for some sort of financial change. One participant noted the current weakened state of our national economy and implied that an economic upturn would be necessary before LID would be able to really gain ground. Several others believed that more affordable options, or more comparably priced options, would be important for the advancement of LID, while someone else emphasized the need for incentives. Access to comprehensive financial comparisons or cost-benefit analyses that incorporate true life-cycle costs was deemed a valuable tool for justifying the use of LID. An equal number of respondents, just over twenty-five percent felt that both political and educational changes were necessary to make the use of LID more likely. Representatives from both the public and private sector stated that codifying or mandating certain requirements was a 'necessary evil' before the use of LID would become more prevalent. Unfortunately, many are set in existing ways and will only do what is required. Not only would policy change address this, it would also provide an easier medium for enforcement. As for education, the client was recognized most frequently as the party lacking knowledge; however, the importance of improved education among all project members was cited as critical, as well as for those in government agencies. Just over ten percent of participants voiced the need for more research and better access data, in order to effectively support and promote the usage of LID. The same percentage also stressed a need for an improved understanding of the maintenance requirements and expectations by all parties involved. One individual felt limited to some degree by plant palette and would like to see an increased number of nurseries growing more wetland material. A greater variety of plants would provide a greater opportunity for usage of LID techniques.

38. a. Are there any particular codes, regulations, or policies (local, state, or federal) that you feel inhibit your use of LID?

Looking for more specific barriers, participants were asked if there were any particular codes, regulations, or policies, at any level of government, that were inhibiting their use of LID. Although a few of the total participants that responded to this question replied with a decisive no (twenty-five percent), a greater proportion (thirty-eight percent) felt there were not specific regulations or codes that were restrictive, but it was more about the current codes lacking in support or promotion of LID. Several respondents cited specific regulations one of which was zoning codes. In addition, rules associated with the historic downtown area of Charleston were identified as limiting to LID for two particular reasons. The first is related to the previously discussed restrictions with plant palette and the second is the height restriction which creates a premium on land and forces developers to maximize square footage since there are vertical limitations, leaving no extra horizontal space for LID techniques. Finally, two manuals were identified as prohibitive, the Manual of Uniform Traffic Control Devices and any stormwater manual. The traffic manual is a document issued by the Federal Highway Administration and is essentially the standard by which many road-related decisions are made. According to the respondent, it is very incompatible with LID concepts such as vegetated swales or impervious roadway surfaces. In fact, throughout the survey process, numerous participants alluded to the fact that the copious regulations of the federal and state Departments of Transportation had a significant role in influencing LID. This incompatibility is unfortunate because roads often have large areas of open, linear land associated with them and the many miles of paved roads in the region provide a great opportunity for accommodating the sometimes land-consumptive LID techniques. The stormwater manuals were considered problematic because, according to the respondent, essentially every state manual was created by one of two companies that specialize in this field of engineering. As a result, these extremely conservative documents create very specific blanket requirements without truly understanding the regional differences. Therefore there are often broad requirements that do not always translate well to every area, but are still considered the standard by which engineers adhere.

Part Seven: Opportunities

Participants were asked the following open-ended questions in order to encourage them to ‘think outside of the box’ and provide possible direction as to which of the region’s resources could be further explored as a means for promoting LID.

39. Are you aware of any new technologies that might facilitate any step of the design and implementation of LID techniques? Please explain.

When questioned about new technologies, over half of respondents were not aware of any new technologies that might be beneficial to the design and implementation of LID treatments. In fact, one respondent felt that the idea behind LID was to have less technology and rely more on nature. Out of all the answers received, twenty-nine percent were related to some sort of design-aid tool. The technologies included Geographic Information Systems (GIS) and various computer modeling and imaging software. Three responses related to new product technologies. One general comment implied that the market had caught on to the idea of LID and that there were a number of companies working on new, cost-effective products. These new products seem to aim at providing turnkey solutions; two examples of such products were mentioned by separate individuals: Filterra, a stormwater bioretention filtration system and pre-fabricated urban rain garden kits. One participant noted that many manufactured products today often promote their products as ‘LEED-rated’ and implied that this type of marketing can be beneficial to LID.

40. Do you perceive any overall trends regarding LID?

As a result of the interactions and exposure involved with respondents’ particular professions, most would likely be aware of current trends in land development;

therefore each was questioned about whether they perceived any trends related to Low Impact Development. Ninety percent mentioned they had noticed some type of a trend with LID. Of these responses, forty-two percent were related to education in some regard. Generally, there was a recognized increase in overall awareness on the part of the public, as well as development professionals. Greater knowledge is directly correlated with a greater acceptance. In addition to the education trends, almost thirty-two percent commented that LID was becoming more common and over time, likely more mainstream. Another thirty-two percent highlighted specific treatments that were gaining momentum, including pervious pavements, vegetated swales, bioretention, and inlet filters.

41. What specific actions can the “green” movement take to further the spread of LID?

With the 'green' movement having considerable recognition and momentum in our society today, participants were asked about the specific actions the movement could take in order to help further the spread of LID. Over half of those that responded again acknowledged the value of education and awareness among both the general public and professionals. Respondents felt the focus should be on demonstrating the merit of alternative techniques through direct comparisons with more conventional techniques that detail the specific benefits and impacts of LID. These demonstrations should be tailored to the intended audience, emphasizing areas that are of significance to each group. Strong arguments for development of this type are best supported through comprehensible financial and scientific data. Just under a quarter of participants stressed the importance of not only enlightening, but guiding individuals through some sort of policy or regulation. Without any sort of formal codification, it was felt that there would be minimal change. Anecdotal support was provided by one participant whom noted that Germany, widely known for its less than sunny climate, was a leader in solar energy. This position was attributed to government support with laws that encourage businesses to enter into the clean energy sector. In addition, two participants advocated a need for a shift from a predominantly 'green building' focus to include more of a 'green landscape' concentration. Although changing building practices is a critical component of creating a more sustainable culture, there is a limited emphasis on the importance of green infrastructure.

42. How can the rich natural and cultural resources of the Charleston region, such as its parks, beaches, plantation, and historic sites be used to support and encourage the use of LID?

Understanding how to best capitalize on BCD region resources that might be considered favorable to the support, awareness, cost-efficiency, and application of sustainable alternatives to stormwater management is an important step in advancing the LID movement. Charleston’s parks, beaches, plantations, and historic sites were recognized as being an important educational tool; sixty-five percent of those that responded believed that these community places naturally lend themselves to the use of LID techniques. These local favorites are often the perfect fit for LID treatments, as they offer plenty of space and a natural palette. Educational components can be formal such as demonstration projects and interpretive signage or more implied.

In addition, the public realm was noted as an excellent medium for leading by example and setting precedents for the commercial sector to follow. Not only are the LID techniques valuable for their educational role, but they can also help preserve the natural aesthetic that defines many of these regionally significant places. Many of the people that call Charleston home have a fondness for the natural beauty that surrounds the area. One respondent stressed the interrelated nature of awareness and preservation. People must be made aware of the vulnerability of the natural resources that they so highly value in order for the need for change to be recognized and supported.

43. Any additional comments?

No new information was discussed during this question. Generally, participants used this question to reinforce previous points or to further inquire about this research project.

Summary

Organized via the main aspects of my research questions, the following key points were identified in the survey results:

Survey Respondent's Background

1. Survey results are based on responses from fourteen landscape architects, four planners, and two civil engineers from the BCD region.

LID Awareness

2. Survey respondents were most knowledgeable about stormwater regulations in Charleston County.
3. Among all the LID treatment options, extended detention basins were rated as most influential to water quality while also having the lowest maintenance requirements. Contrary to this perception, recent regional studies have shown that extended detention basins may not be as beneficial to water quality as reported in national studies and do require regular maintenance for proper functioning, not just for aesthetics.

4. Knowledge of local stormwater regulations varied drastically between civil engineers, who rated themselves 'extremely knowledgeable' and landscape architects, whom rated themselves significantly lower. Landscape architects noted they ranked themselves this way because engineers are relied upon to possess this information.

5. The overall knowledge and awareness of ASLA'S land-based Sustainable Sites Initiative was limited among all survey respondents

LID Usage

6. LID is being used in the BCD region primarily for its functional ability to manage stormwater on site and not with the goal of improving watershed quality broadly across the region.
7. A vast majority of LID in the BCD region occurs in new development; this may be attributed to the significant growth in the region and/or may be a result of limitations in dealing with retrofit project sites
8. LID is most likely to occur in commercially zoned projects.
9. Most of the LID projects in the tri-county region are occurring in Charleston County.
10. Regarding usage of specific LID treatments, there is a strong correlation between treatments most commonly used in both LEED and non-LEED projects and familiarity with LID treatments, LID treatments perceived to be easiest to implement, and availability of data and resources on specific LID techniques, i.e. pervious pavements. Further, regarding usage of specific LID treatments, there is a strong correlation between lack of LID treatments and lack of familiarity with concept and specific techniques, perceived difficulty to implement LID techniques, and lack of available data and resources, i.e. engineered wetlands.

Perceived LID Benefits

11. LID techniques are being recognized for their ability to meet various stormwater requirements and regulations.
12. Although environmental benefits were recognized as valuable to all survey respondents, the most significant benefit identified for clients was the ability to display some sort of quantifiable financial return.

Perceived LID Barriers

13. One of the most important factors influencing the use of all eight of the LID techniques was maintenance, particularly the more naturalized treatments such as bioretention. Key concerns regarding the lack of LID usage relate to: additional costs for the property owner, the importance of proper maintenance for both functionality and aesthetics reflecting on the designer, and the long-term accountability from the perspective of the municipality.
14. A lack of formalized support of LID in the form of policies and incentives was recognized as a significant barrier.
15. Lack of regionally relevant sources of LID performance data and design guidance were noted as significant reasons to not implement LID on projects.
16. There appears to be conflicts with state and federal transportation regulations and LID approval.

17. Potential barriers to LID usage were also ascribed to the unequal distribution of influence of project team members (i.e. engineers generally have more influence) and an overall lack of collaboration across the team (i.e. landscape architects brought in to collaborate AFTER stormwater management decisions have been made). This might be related to limited awareness among the development community of the qualification of landscape architects to design stormwater management solutions; where landscape architects may possess a greater emphasis on sustainable solutions
18. Although LEED is an established program that may appear to be an effective medium for promoting the use of LID treatments, survey respondents felt LEED hindered the use of LID more than it facilitated it.
19. Because the emphasis of LEED is on the built environment rather than the natural environment, LEED points for stormwater management are limited.
20. The LEED point system often misdirects the focus of project owners from developing sustainable projects to earning points.
21. The intent of LID and landscape design principles was found to be incompatible only when dealing with the urbanized and historic areas of downtown Charleston. The preferred natural plant palette of many LID treatments contrasts with the exotic plant palette preference of the historic downtown area. Further, the height restriction and general premium for land in the urbanized downtown area, does not allow for the typically large

space requirements of some LID treatments (i.e. detention basins), as well as may negatively impact circulation in tight space restricitions.

22. Survey respondents felt the best way to facilitate greater usage of LID, was to focus on financial factors surrounding LID.
23. Charleston's physiographical characteristics (groundwater, soils , and precipitation events) are all considered rather difficult obstacles to overcome for implementing LID in the region.
24. Reliance on and limited availability of appropriate plant materials at regional nurseries was also seen as a key barrier to LID implementation.

Opportunities for Promoting LID

25. Because states typically focus on stormwater rates and not volume, LEED has potential to support the use of LID treatments as it emphasizes both water quality and water quantity controls. Additionally, there are a significant number of self-proclaimed LEED-rated products on the market today.
26. The most recognized and utilized resource for LID design guidance is the internet.
27. Many survey respondents recognized a need for codes or mandates to 'coerce' and more easily enforce the consistent use of LID.
28. Survey respondents felt that the abundance of natural and cultural amenities in the BCD region lent themselves to LID

29. Survey respondents were not aware of tax credits for LID and did not feel if they existed locally that they might be worth the effort to uncover and understand, hence were considered of little importance to support LID usage broadly. However, successful use of incentives for LID usage by municipalities across the country shows this to be an important step in encouraging LID.

Conclusion

Overall, a lot of valuable information was garnered through the use of this survey instrument. The range of questions, style of data collection, and total number and variety of land development professionals included in the survey produced robust data, which generally assisted to answer my research questions related to LID usage, awareness, benefits, barriers, and opportunities. If applied appropriately, the key points isolated from this research have the potential to improve the usage of LID in the BCD region.

CHAPTER TEN

CONCLUSION

Although the original goal of stormwater management was to provide for the safety of human beings and their property, the consequences of conventional management approaches along with the needs and desires of a growing and more ecologically-minded population have expanded stormwater management into a multi-faceted and complex entity. Current comprehensive stormwater management approaches are desired that can adequately address these multiple objectives, as represented by Low Impact Development (LID). Examples of successful LID projects are evident in cities across the U.S., while other regions are still trying to figure out how to make LID work locally.

The purpose of this thesis was to assess the state of Low Impact Development in the BCD region of South Carolina in order to understand current patterns of LID awareness and usage, as well as regionally relevant benefits, obstacles, and opportunities. An important component inherent in this work has been comprehension of the current role of landscape architects in regards to regional LID usage and proliferation, and the potential role they could have to influence the increased use of LID in the BCD. Through synthesis of this information, directed approaches are proposed to assist the BCD region with creation and enhancement of an environment supportive of LID.

Assessment and Suggestions

In order to determine whether I was able to answer my research questions, it is imperative to revisit them:

As of 2011, what is the state of LID in the Berkeley-Charleston-Dorchester (BCD) region of coastal South Carolina?

1. What levels of LID awareness and usage exist in the region?
2. What are the perceptions of the benefits, barriers and opportunities for LID?
3. What strategies might facilitate widespread usage of LID in the BCD region?

The following recommendations, intended to facilitate the use of LID in the BCD region, are broadly organized according to my original research questions.

Awareness

These suggestions are targeted at increasing overall awareness and knowledge among both professionals and the public of the BCD region:

1. Green certification programs have proven to be beneficial for drawing attention to a cause, providing quantifiable means for measuring environmental sensitivity, and spurring technological advance; therefore,

there is value in promoting and advocating the use of such programs among local developers, professionals, and government officials. In order for it to be truly effective at promoting LID, the program must not be centered on the built-environment, but rather on sustainable land development and management practices, such as ASLA's Sustainable Sites Initiative (SSI). To encourage greater access and usage, the program should be made affordable to all. Existing national programs, such as SSI, should be advocated within the BCD region, or a regionally-based green certification program should be developed.

2. By nature of the profession, landscape architects generally have a strong focus on the land. Unfortunately, the lack of knowledge regarding local stormwater regulations may be preventing landscape architects from assuming a greater role in influencing decisions related to stormwater management on development projects. If state or local requirements pertaining to stormwater knowledge for landscape architect's were more comparable with those for engineers, landscape architects might be recognized for their stormwater design capabilities and consulted in the initial stages of project development.

3. Creative educational initiatives are imperative for engaging the public and professionals. Professionals appear to rely on stormwater techniques with

which they are most familiar, so inciting change requires education to improve knowledge and confidence. From a public standpoint, the abundance of naturalized public sites in the BCD region provides the perfect environment for LID demonstration projects, plenty of land and regular public involvement. Other means for producing successful educational initiatives potentially lie with the ability to link financial incentives with education and stewardship opportunities, as most all individuals seem to respond to financial motives.

4. Ensuring land development professionals are staying abreast of current research and trends with regards to alternative stormwater management techniques would help ensure that these professionals are equipped with the proper knowledge to make judicious decisions regarding LID usage. Mandatory certification programs and continuing education requirements for professionals involved with stormwater management would be a valuable means for making sure that decisions are being made based on sound reasoning and not solely on familiarity and ease of implementation.

5. In the BCD region it appears that LID usage is motivated by financial gain and practicality of meeting requirements rather than its original intent -- improving and protecting the hydrologic function of a region. A government-sponsored local campaign aimed at raising awareness of the

compromised health of regional waterways might prompt both land development professionals, as well as developers to incorporate more LID techniques for the greater good of the region instead of just for financial or practical reasons. To increase the viability of this type of campaign, it could be coupled with an incentive program to encourage those that would not otherwise choose to incorporate LID.

Benefits

The following proposals attempt to address approaches for capitalizing on the motivations of those in the BCD region:

1. Regional incentives are either lacking or are not significant enough to promote LID usage. Almost all aspects of land development, as well as all of the professionals involved, are financially motivated in some capacity or another. The proper incentive can be a valuable tool not only for spurring LID usage but also for promoting development and directing it to where it is desirable, such as in specific counties or to achieve certain densities. Key land development figures could be surveyed for input regarding appropriate incentives, which could be used to achieve regional development goals.

2. Financial motives have been identified as a significant factor in land development and will likely always be. With the lifecycle costs of certain LID techniques comparable to conventional stormwater management approaches, there is a strong need to produce regionally applicable cost-benefit analyses data that is easily accessible. Mediums for promoting the gathering of this type of data should be explored in the BCD region.

Barriers

Suggestions in this section attempt to highlight where efforts should be focused in order to overcome regional barriers identified in the survey:

1. Concerns over proper maintenance and issues of accountability can plague LID usage from beginning to end. Not only are cost and accountability concerns directly prohibiting the potential usage of LID treatments, but improperly maintained treatments not only have the potential to fail or improperly function, but may also project an undesirable aesthetic. For this reason, there is a strong need to formally regulate and track LID ownership and/or maintenance obligations. This effort may be further reinforced through the use of financial repercussions. In addition, there is a need for reliable maintenance guidelines related to proper care and frequency.

2. Physical size and space requirements of many LID treatments can be of concern when attempting to implement them. These physical requirements can create issues in urban areas where space is already limited, particularly in downtown Charleston where height restrictions create a greater emphasis on dense development in an effort to maximize developable land. Space consuming LID treatments may also interfere with circulation patterns. Issues with space requirements highlight a need for identifying existing modular LID alternatives, or developing new ones.

3. LID treatments, intended to take advantage of existing local ecological systems, can be perceived as problematic, both functionally and aesthetically. Functionally, there is a much greater degree of uncertainty of water holding and distribution capacity when naturalized systems are utilized for stormwater management as compared with engineered systems. To provide similar levels of credibility and reliability, significant amounts of data on the capabilities and capacity of representative natural systems must be generated and tested. As a result of the variability of relevant site factors and the challenging geographic and climatic conditions of the BCD region, it is critical that regionally applicable data be gathered. Promoting pilot projects or partnering with local universities and research–based institutions can be useful to spur data collection. Further,

formulation of an appropriate medium for presenting and accessing these regionally relevant data will be necessary.

4. Aesthetically, 'naturalized' systems consistent with many LID treatments may not be visually suitable for more manicured environments, such as the historic downtown area of Charleston or in regions that do not find this naturalized look to be preferable or perceive it to be too wild. Researching or designing more manicured LID alternatives would increase the opportunities available for using LID in a greater variety of environments.

5. Evaluating and changing long-standing stormwater management policy can be difficult and time consuming, but also beneficial toward the creation of new opportunities such as LID. In particular, roads and right-of-ways are a highly regulated form of development with the potential to support and showcase LID, hence approaching state and local road and development authorities is critical.

6. Frequently, developers are interested in knowing and meeting only the minimum requirements; this apathy is likely a result of financial motives. Generation of local stormwater management codes and mandates to guide and encourage specific behaviors, while also providing a means for measuring and enforcing desired degrees of water quantity and quality

controls would be valuable. Creating uniform regulations across county lines would streamline processes and provide consistent levels of expectations among those in the development community, as well as provide a good role model for individual municipalities. In fact, it may be valuable to solicit the input of representatives from the development community during efforts to change existing or create new policy.

7. Accountability and liability drive the need for regionally relevant sources of alternative stormwater management performance data in order to provide confidence in approaches such as LID. The BCD region should find creative means for promoting and incentivizing the gathering of performance data from local projects, such as refunding stormwater fees for each year data is submitted. Data should be made easily accessible in a central repository.

Limitations and Future Research

Upon reflection of the work undertaken as a part of this thesis research, it is clear that there were limitations in the processes I chose; however as a result there are opportunities for future research.

Regarding limitations, the survey process involved lengthy one-on-one interviews with local land development professionals from the BCD; however, the process was time consuming and hence limited the total number of survey respondents. Future research might supplement the one-on-one interviews with an abbreviated version of the survey mailed, emailed, or web-based to a greater number of land development professionals.

Although a diverse sampling of land development professionals was included from both the private and public sector, as this was a landscape architecture focused thesis, perspectives may be skewed towards landscape architect's in the private sector, as that was the largest group in this survey population. Future research might solicit additional perspectives from under-represented sample groups or expand to include other relevant perspectives such as those of the developer, the general public or state agencies, such as DOT. It might also be valuable to use the same survey to interview land development professionals in a region widely recognized for its LID usage, such as Portland, Oregon and compare survey responses with those received from the land development professionals in the BCD region of South Carolina.

Finally, as the survey was originally designed to be administered to landscape architects, when additional land development professionals were interviewed using the survey, some of the questions were not applicable and others had to be slightly reworded, sometimes altering the meaning slightly. Suggestions for future research would include multiple versions of a similar survey, specifically designed for each profession.

APPENDICES

Appendix A

Survey: Alternative Stormwater Techniques and Barriers

1 SURVEY: Alternative Stormwater Management Techniques and Barriers

Introduction

This is an independent research effort for my Master's thesis in partial fulfillment of the requirements for the Degree of Master of Landscape Architecture at Clemson University. The focus of this survey is to understand patterns of awareness, design, use and opportunities specific to alternative stormwater management techniques within the metropolitan region of Charleston, South Carolina among local landscape architects. Alternative approaches to the conventional structural or "pipe and gutter" method are an attempt to manage stormwater at the site level in an environmentally sensitive manner. There are a range of techniques that comprise this alternative approach and collectively, they are commonly referred to as 'low impact development,' or LID. Some examples of LID alternative stormwater management techniques include: rain gardens, bioretention, pervious pavement, cisterns, and green roofs. Recent initiatives, such as the U.S. Green Building Council's "Leadership in Energy and Environmental Design" (LEED)programs and the American Society of Landscape Architects "The Sustainable Sites Initiative" (SSI), are certification programs that attempt to promote environmentally-friendly changes in land development and management practices through quantifiable means. LID techniques are commonly utilized by professionals in order to receive credit towards the certification of a LEED or SSI project.

It is important to note that in addition to LID, there are a variety of other terms used to describe this alternative approach to stormwater management including: green engineering, sustainable stormwater management, natural drainage, and stormwater best management practices to name a few. For simplicity purposes, this survey will use the term LID to collectively refer to this sustainable approach to stormwater management.

Also, please keep in mind that when questions are asked about specific projects, _answers should be based on projects that have been implemented in the metropolitan region of Charleston, South Carolina_ (which includes Charleston, Berkeley, and Dorchester counties).

The purpose of this survey is fourfold:

- **First, based on my literature search of traditional and alternative stormwater management approaches, and more specifically the barriers that appear to be in place within the Charleston metro region to implement alternative stormwater management practices, I want to survey local Landscape Architects to gauge overall awareness of the concept of 'LID';**
- **Second, based on that level of awareness, I want to identify how, where, and why specific LID techniques are currently being used in the Charleston metro region and to what success;**
- **Third, I want to assess the real and perceived barriers and benefits to using LID and understand how each can effectively promote or inhibit the use and implementation of LID in coastal projects; and**
- **Lastly, I want to identify any opportunities that may exist for advancing more sustainable approaches to stormwater management, such as LID.**

PART ONE: BACKGROUND INFORMATION

Date of Interview:	
Name of Organization:	
Disciplines in Organization:	
Interview Participants (names):	
Breadth of Participant Occupations/Titles:	
Contact information:	

PART TWO: AWARENESS

The overarching terms "Low Impact Development or LID" and "Green Infrastructure" have been used in recent years by many municipalities attempting to incorporate more sustainable stormwater management approaches into their jurisdictions. In looking at both new areas being developed as well as infill areas being redeveloped, municipalities are advocating numerous types of in situ water infiltration and management techniques, as well as encouraging the use of programs such as LEED, etc. to improve development and redevelopment in their jurisdictions on a site by site basis.

For the following questions, please use the six-point scale, where "1" is "No Knowledge" and "6" is "Very Knowledgeable."(Circle a number)

1. **Please indicate how knowledgeable you are with the LEED certification process (i.e. if you have passed the LEED exam you are considered very knowledgeable):**

No knowledge					Very knowledgeable	Do not know
1	2	3	4	5	6	7

2. **Please indicate how knowledgeable you are with ASLA's Sustainable Sites Initiative (SSI) (i.e. if you can identify a specific case study, you are considered very knowledgeable):**

No knowledge					Very knowledgeable	Do not know
1	2	3	4	5	6	7

3. **Please indicate how knowledgeable you are with specific county regulations regarding stormwater management: (name county:______________________)**

No knowledge					Very knowledgeable	Do not know
1	2	3	4	5	6	7

a. **For each additional county within which you have worked, please indicate how knowledgeable you are with their specific county regulations regarding stormwater management:**

County:____________________

No knowledge					Very knowledgeable	Do not know
1	2	3	4	5	6	7

County:____________________

No knowledge					Very knowledgeable	Do not know
1	2	3	4	5	6	7

4. **Please indicate how *__knowledgeable__* you are about each LID technique (i.e. if you have practical experience in the design and or implementation of the techniques, you are considered very knowledgeable):**

	No knowledge					Very knowledgeable	Do not know
Pervious pavements	1	2	3	4	5	6	7
Bioretention	1	2	3	4	5	6	7
Open-space/buffer preservation	1	2	3	4	5	6	7
Inlet/filter systems	1	2	3	4	5	6	7
Extended detention basins (dry or wet)	1	2	3	4	5	6	7
Below-ground detention/ infiltration	1	2	3	4	5	6	7
Vegetated swales	1	2	3	4	5	6	7
Engineered wetlands	1	2	3	4	5	6	7

PART THREE: USE

Today, terms such as sustainability, eco-friendly and “green” have become quite ubiquitous in our culture. Although intentions may be sincere, often the practical application of these concepts can be more elusive. Many states and localities have drafted alternative stormwater management manuals which provide support to professionals. While there are no specific resources of this nature currently available within the state or the Charleston region, professionals and the general public are finding means to incorporate LID techniques in order to achieve specific stormwater management goals.

5. **Have you ever implemented LID in a project in the Charleston metro region**?... YES or NO

For the following questions, please use the six-point scale, where "1" is "Very Dissatisfied" and "6" is "Very Satisfied."(Circle a number)

6. **Please rate how satisfied you are with the total *number* of your projects that have included LID techniques:**

Very dissatisfied					Very satisfied	Do not know
1	2	3	4	5	6	7

7. **Please rate how satisfied you are with the *results* of your projects that have included LID?**

Very dissatisfied					Very satisfied	Do not know
1	2	3	4	5	6	7

8. **Approximately how many of your projects in the Charleston metro region since January2010 included LID elements/techniques? (Circle one)**

None	5 or less	6-10	11-20	20 or more

   a. **Roughly, what percentage of your total Charleston region projects does this number represent?**

None	less than 10%	11-25%	26-50%	more than 50%

9. **What practices do you most commonly use to manage stormwater sustainably? (Check the 3 most common)**

	Reduce impervious cover
	Disconnect impervious surfaces
	Provide depression storage in landscape
	Convey stormwater in swales to promote infiltration
	Use biofiltration to provide vegetated and soil filtering
	Evapotranspire (use vegetation in landscaping, biofiltration, etc. to max evapotranspiration potential)
	Infiltrate stormwater (permeable pavement, infiltration basins and trenches)
	Maintain natural drainage courses
	Minimize use of clearing and grading

   a. **Please provide examples of the LID techniques that were used to achieve these goals:**

10. Please indicate what percent of your projects that incorporate LID are of each type:

Residential	%
Commercial	%
Industrial	%

New Development	%
Retrofit	%

Private	%
Public	%

For the following questions, please use the six-point scale, where "1" is "Never" and "6" is "Every project."(Circle a number)

11. Please indicate how often you apply LEED stormwater criteria to your stormwater management solutions on non-LEED projects:

Never					Every project	Do not know
1	2	3	4	5	6	7

12. Please indicate how often you apply your Sustainable Sites Initiative (SSI) knowledge to stormwater management on non-SSI projects:

Never					Every project	Do not know
1	2	3	4	5	6	7

13. Please indicate how often your use of *alternative* stormwater management techniques are hindered by specific *county* regulations: (name county:____________________)

Never					Every project	Do not know
1	2	3	4	5	6	7

14. Please indicate how often your use of *alternative* stormwater management are hindered by specific *municipality* regulations regarding stormwater management: (name municipality:____________________)

Never					Every project	Do not know
1	2	3	4	5	6	7

15. Please indicate how often your use of *alternative* stormwater management techniques in projects are hindered by landscape design principles such as creating "place":

Never					Every project	Do not know
1	2	3	4	5	6	7

a. In your opinion, do you believe LID techniques generally detract from the qualities of a "place" such as aesthetics, livability, and connectivity?............YES or NO

16. Based on your experience, which group do you feel generally exerts the most influence over stormwater management today? (Please check one)

Landscape architects	
Engineers	
Developers	
Clients	
Local government	
State government	
Federal government	
General public	
Other (please specify:)	

17. When LID techniques have been used in projects for stormwater management, which of the following is the most common PRIMARY goal. (Please check one)

Manage stormwater on site	
Protect/restore riparian zones, wetlands, buffers, etc	
Protect/enhance water quality	
Reduce burden on community stormwater systems	
Store and harvest to reduce potable water needs	
Provide additional site amenity	
Other (please specify):	

18. Have you ever used LID techniques to achieve credit toward any certification initiative such as LEED or SSI?................. YES or NO

a. Which techniques have you most commonly used in LEED projects (Check all that apply)?

Pervious pavements	
Bioretention	
Open-space/buffer preservation	
Inlet/filter systems	
Extended detention basins (dry or wet)	
Below-ground detention/ infiltration	
Vegetated swales	
Engineered wetlands	
Other (please specify):	

The following question pertains to frequency of use of specific LID techniques. Please use the six-point scale, where "1" is "Never" and "6" is "Frequently."(Circle a number)

19. When using LID in a project, how *often* do you incorporate each technique?

	Never					Frequently	Do not know
Pervious pavements	1	2	3	4	5	6	7
Bioretention	1	2	3	4	5	6	7
Open-space/buffer preservation	1	2	3	4	5	6	7
Inlet/filter systems	1	2	3	4	5	6	7
Extended detention basins (dry or wet)	1	2	3	4	5	6	7
Below-ground detention/ infiltration	1	2	3	4	5	6	7
Vegetated swales	1	2	3	4	5	6	7
Engineered wetlands	1	2	3	4	5	6	7

The following question pertains to the overall ease of use of specific LID techniques . Please use the six-point scale, where "1" is "Extremely easy" and "6" is "Extremely cumbersome."(Circle a number)

20. Based on your experience, how *easy to implement* is each technique:

	Extremely easy					Extremely cumbersome	Do not know
Pervious pavements	1	2	3	4	5	6	7
Bioretention	1	2	3	4	5	6	7
Open-space/buffer preservation	1	2	3	4	5	6	7
Inlet/filter systems	1	2	3	4	5	6	7
Extended detention basins (dry or wet)	1	2	3	4	5	6	7
Below-ground detention/ infiltration	1	2	3	4	5	6	7
Vegetated swales	1	2	3	4	5	6	7
Engineered wetlands	1	2	3	4	5	6	7

The following SEVEN questions are focused on factors influencing the use of specific LID techniques. Please use the six-point scale, where "1" is "Not at all important" and "6" is "Very important."(Circle a number)

21. Generally speaking, when *PERVIOUS PAVEMENTS* were implemented, rate how strongly each factor influenced the decision to use it:

	Not at all important					Very important	Do not know
Maintenance requirements	1	2	3	4	5	6	7
Ability to reduce hard infrastructure	1	2	3	4	5	6	7
Cost efficient	1	2	3	4	5	6	7
Ability to meet LEED requirements	1	2	3	4	5	6	7
Eco-friendly image/appeal	1	2	3	4	5	6	7
Tax credits, incentives available	1	2	3	4	5	6	7
Prior use/knowledge of specific technique	1	2	3	4	5	6	7
Impact on water quality/watershed health	1	2	3	4	5	6	7

22. Generally speaking, when *BIORETENTION* was implemented, rate how strongly each factor influenced the decision to use it:

	Not at all important					Very important	Do not know
Maintenance requirements	1	2	3	4	5	6	7
Ability to reduce hard infrastructure	1	2	3	4	5	6	7
Cost efficient	1	2	3	4	5	6	7
Ability to meet LEED requirements	1	2	3	4	5	6	7
Eco-friendly image/appeal	1	2	3	4	5	6	7
Tax credits, incentives available	1	2	3	4	5	6	7
Prior use/knowledge of specific technique	1	2	3	4	5	6	7
Impact on water quality/watershed health	1	2	3	4	5	6	7

23. Generally speaking, when *INLET/FILTER SYSTEMS* were implemented, rate how strongly each factor influenced the decision to use it:

	Not at all important					Very important	Do not know
Maintenance requirements	1	2	3	4	5	6	7
Ability to reduce hard infrastructure	1	2	3	4	5	6	7
Cost efficient	1	2	3	4	5	6	7
Ability to meet LEED requirements	1	2	3	4	5	6	7
Eco-friendly image/appeal	1	2	3	4	5	6	7
Tax credits, incentives available	1	2	3	4	5	6	7
Prior use/knowledge of specific technique	1	2	3	4	5	6	7
Impact on water quality/watershed health	1	2	3	4	5	6	7

24. Generally speaking, when *EXTENDED DETENTION BASINS (WET OR DRY)* were implemented, rate how strongly each factor influenced the decision to use it:

	Not at all important					Very important	Do not know
Maintenance requirements	1	2	3	4	5	6	7
Ability to reduce hard infrastructure	1	2	3	4	5	6	7
Cost efficient	1	2	3	4	5	6	7
Ability to meet LEED requirements	1	2	3	4	5	6	7
Eco-friendly image/appeal	1	2	3	4	5	6	7
Tax credits, incentives available	1	2	3	4	5	6	7
Prior use/knowledge of specific technique	1	2	3	4	5	6	7
Impact on water quality/watershed health	1	2	3	4	5	6	7

25. Generally speaking, when *BELOW GROUND DETENTION/INFILTRATION* were implemented, rate how strongly each factor influenced the decision to use it:

	Not at all important					Very important	Do not know
Maintenance requirements	1	2	3	4	5	6	7
Ability to reduce hard infrastructure	1	2	3	4	5	6	7
Cost efficient	1	2	3	4	5	6	7
Ability to meet LEED requirements	1	2	3	4	5	6	7
Eco-friendly image/appeal	1	2	3	4	5	6	7
Tax credits, incentives available	1	2	3	4	5	6	7
Prior use/knowledge of specific technique	1	2	3	4	5	6	7
Impact on water quality/watershed health	1	2	3	4	5	6	7

26. Generally speaking, when *VEGETATED SWALES* were implemented, rate how strongly each factor influenced the decision to use it:

	Not at all important					Very important	Do not know
Maintenance requirements	1	2	3	4	5	6	7
Ability to reduce hard infrastructure	1	2	3	4	5	6	7
Cost efficient	1	2	3	4	5	6	7
Ability to meet LEED requirements	1	2	3	4	5	6	7
Eco-friendly image/appeal	1	2	3	4	5	6	7
Tax credits, incentives available	1	2	3	4	5	6	7
Prior use/knowledge of specific technique	1	2	3	4	5	6	7
Impact on water quality/watershed health	1	2	3	4	5	6	7

27. Generally speaking, when *ENGINEERED WETLANDS* were implemented, rate how strongly each factor influenced the decision to use it:

	Not at all important					Very important	Do not Know
Maintenance requirements	1	2	3	4	5	6	7
Ability to reduce hard infrastructure	1	2	3	4	5	6	7
Cost efficient	1	2	3	4	5	6	7
Ability to meet LEED requirements	1	2	3	4	5	6	7
Eco-friendly image/appeal	1	2	3	4	5	6	7
Tax credits, incentives available	1	2	3	4	5	6	7
Prior use/knowledge of specific technique	1	2	3	4	5	6	7
Impact on water quality/watershed health	1	2	3	4	5	6	7

PART FOUR: BENEFITS

Stormwater management has long been dominated by the discipline of engineering, a field that relies heavily on water calculations and models, as mismanagement of stormwater can and has lead to loss of property and life. As LID is a relative new-comer to the realm of stormwater management (generally since the 1990's), suggesting a more sustainable alternative is critical to not only understand the functional benefits of managing stormwater differently than what has been done historically, but to also be able to communicate those benefits to clients, municipalities, etc. Utilizing LID is a conscious design decision to go "against tradition" and recognize there is not only an opportunity to be more ecologically sensitive, but to also influence a movement towards "greener" development practices.

28. When trying to "sell" the concept of LID to clients, government, architects, engineers, etc. on projects – how do you sell the benefits of LID? What aspects do you cite?

29. From your experience, what are client's interpretations of the benefits of LID?

a. Do you agree? Please explain.

30. When you choose to utilize LID, what are the top 3 primary motivations for doing so:

1.____

2.____

3.____

PART FIVE: BARRIERS

Barriers to LID surface during all stages of the development process (i.e. zoning/planning approvals, permits, client review, etc.) and each presents its own set of obstacles; some are real (high water table), some are perceived (assumed to be more costly vs. conventional techniques) some are internal (firm/staff not knowledgeable in techniques), some are external (client reluctance, lack of jurisdiction experience/guidance). Certain barriers are easier to overcome than others.

31. Have you been involved in a project in the Charleston metro region where LID measures were DESIGNED/PROPOSED/PLANNED but ultimately not implemented? …………….YES or NO

For the following sub-questions, please use the six-point scale, where "1" is "Not at all significant "and "6" is "Significant."(Circle a number)

a. If YES, rate each factor below as to how significant of a barrier it was to the implementation of the LID techniques:

	Not at all significant					Very significant	Do not know
Cost of implementation	1	2	3	4	5	6	7
Lack of resources (i.e. design/construction guidelines, etc)	1	2	3	4	5	6	7
Lack of performance data	1	2	3	4	5	6	7
Maintenance requirements	1	2	3	4	5	6	7
Conflicts with municipal code requirements (i.e. curb and gutter, etc)	1	2	3	4	5	6	7
Impact on the qualities of a "place" such as aesthetics, livability, and connectivity	1	2	3	4	5	6	7
High groundwater table	1	2	3	4	5	6	7
Competing space requirements	1	2	3	4	5	6	7
Type of soil	1	2	3	4	5	6	7
OTHER (please specify):	1	2	3	4	5	6	7
	1	2	3	4	5	6	7
	1	2	3	4	5	6	7

b. **If NO, why didn't you use LID in your projects?**

	Not at all significant					Very significant	Do not know
Cost of implementation	1	2	3	4	5	6	7
Lack of resources (i.e. design/construction guidelines, etc)	1	2	3	4	5	6	7
Lack of performance data	1	2	3	4	5	6	7
Maintenance requirements	1	2	3	4	5	6	7
Conflicts with municipal code requirements (i.e. curb and gutter, etc)	1	2	3	4	5	6	7
Impact on the qualities of a "place" such as aesthetics, livability, and connectivity	1	2	3	4	5	6	7
High groundwater table	1	2	3	4	5	6	7
Competing space requirements	1	2	3	4	5	6	7
Type of soil	1	2	3	4	5	6	7
OTHER (please specify):	1	2	3	4	5	6	7
	1	2	3	4	5	6	7
	1	2	3	4	5	6	7

For the following questions, please use the six-point scale, where "1" is "Poor" and "6" is "Excellent."(Circle a number)

32. Based on your experience, please rate the *__availability of resources__* (performance data, design guidance, etc) for each LID technique:

	Poor					Excellent	Do not know
Pervious pavements	1	2	3	4	5	6	7
Bioretention	1	2	3	4	5	6	7
Open-space/buffer preservation	1	2	3	4	5	6	7
Inlet/filter systems	1	2	3	4	5	6	7
Extended detention basins (dry or wet)	1	2	3	4	5	6	7
Below-ground detention/ infiltration	1	2	3	4	5	6	7
Vegetated swales	1	2	3	4	5	6	7
Engineered wetlands	1	2	3	4	5	6	7

PART SIX: NEGOTIATING BARRIERS

Identifying barriers is just one step in the process to further the adoption of sustainable alternatives to stormwater management. Understanding what tools and resources local professionals need and rely on to assist in overcoming barriers, as well as the "paths of least resistance", are crucial components to facilitating the widespread use of these techniques.

For the following question, please use the six-point scale, where "1" is "Easy to overcome" and "6" is "Difficult to overcome."(Circle a number)

33. Which site suitability barriers are the easiest to overcome in the Charleston region?

	Easy to overcome					Difficult to overcome	Do not know
High groundwater table	1	2	3	4	5	6	7
Type of rainstorm events	1	2	3	4	5	6	7
Soils	1	2	3	4	5	6	7
Space constraints	1	2	3	4	5	6	7
Competiton with right-of-way	1	2	3	4	5	6	7
OTHER (please specify)	1	2	3	4	5	6	7
	1	2	3	4	5	6	7

For the following question, please use the six-point scale, where "1" is "Prohibitive" and "6" is "Very supportive."(Circle a number)

34. How supportive of LID would you say the stormwater regulations are at each level of government?

	Prohibitive					Very supportive	Do not know
Municipality	1	2	3	4	5	6	7
County	1	2	3	4	5	6	7
State	1	2	3	4	5	6	7
Federal	1	2	3	4	5	6	7

a. Please provide any additional information about specific municipalities or regulations:

35. **Do you use any stormwater modeling tools?................** YES or NO
    a. If YES, which ones?____

36. **What tools/resources do you utilize for design guidance? (Check all that apply):**

	Another state's manual (please specify):
	Database (please specify):
	Websites(please specify):
	Specific organization (please specify):
	University/affiliates (please specify):
	OTHER (please specify):

37. **Which of the following have you willingly accepted in order to implement LID in a project? (Check all that apply)**

	Reduced profit
	Additional time/costs to educate firm members
	Additional time/costs to educate clients
	Lengthier review process
	Additional collaboration with other disciplines
	OTHER (please specify):

38. **Are there any changes that would need to occur, to make you more likely to utilize LID in projects?**

    a. **Are there any particular codes, regulations, or policies (local, state, or federal) that you feel inhibit your use of LID?**

PART SEVEN: OPPORTUNITIES

Understanding how to capitalize on Charleston region resources that might be considered favorable to the support, knowledge-base, cost, application, etc .of sustainable alternatives to stormwater management is another important step in advancing the movement.

39. **Are you aware of any new technologies that might facilitate any step of the design and implementation of LID techniques? Please explain:**

40. **Do you perceive any overall trends regarding LID?**

41. **What specific actions can the "green" movement take to further the spread of LID?**

42. **How can the rich natural and cultural resources of the Charleston region, such as its parks, beaches, plantations, and historic sites be used to support and encourage the use of LID?**

43. **Any additional comments?**

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